Science and Mathematics Education Centre

An Evaluation of Hands-on Activities in Terms of Learning Environment, Achievement, and Attitudes in Grades 4 and 5

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DECLARATION

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

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ABSTRACT

A sample of 817 Grade 4–5 mathematics students in the diverse school district of Miami-Dade County Public Schools (MDCPS), Florida, USA was involved in an evaluation of the use of hands-on activities in terms of students' achievement, students' attitudes and students' perceptions of the mathematics classroom environment. Other aims included validating generally-applicable measures of classroom learning environments and students' attitudes to mathematics, and investigating associations between the classroom learning environment and the student outcomes of performance and attitudes.

The study was conducted in two phases. Phase 1 had a sample of 442 participants and classroom environment was assessed with scales selected from the My Class Inventory, Questionnaire on Teacher Interaction and Science Laboratory Environment Inventory. Factor analysis provided a degree of support for the factorial validity and internal consistency reliability (using Cronbach's alpha coefficient) for each of five classroom environment scales. Because of the small number of items per scale (15 items in five scales for the My Class Inventory, 12 items in four scales for the Question on Teacher Interaction and 15 items in five scales for the Science Laboratory Environment Inventory) in Phase 1, it was not possible to replicate the *a priori* factor structure of each instrument scale. Scale reliabilities generally were acceptable.

Phase 2, involving a sample of 375 Grades 4 and 5 students in four elementary schools, was necessary because questionnaires in Phase 1 had too few items to enable the researcher to establish satisfactory levels of reliability and validity. The What Is Happening In this Class? (WIHIC) was modified to four scales and 29 questions for use in Phase 2. Factor analysis supported the structure of the WIHIC and internal consistency reliability was satisfactory for two units of analyses, namely, the individual and the class mean.

In Phase 1 of the study, differences between an experimental group (that used manipulatives for 60% of the time) and a control group (that used manipulatives for less than 40% of the time), were described in terms of the effect size (magnitude of the difference in standard deviations) and statistical significance for each learning environment, attitude, and achievement scale. Differences between the pretest and posttest for the set of six dependent variables (Student Cohesiveness, Teacher Support, Task Orientation, Cooperation from the WIHIC and Adoption of Mathematical Attitudes and Enjoyment of Mathematics Lessons for the TOMRA) were analyzed in Phase 2 using a MANOVA for repeated measures. Effect sizes were used to describe the magnitude, as distinct from the statistical significance, of pre-post changes.

In Phase 2, associations between student attitudes and their perceptions of the learning environment were relatively weak for both pretest and posttest data with either the individual or the class mean as the as the unit of analysis. These results were unexpected and are inconsistent with past research, therefore highlighting the need for further research.

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CHAPTER 1

BACKGROUND AND RATIONALE

1.1 Introduction

The role of mathematics in educating the workforce is crucial for the well being of a nation. Scientists and engineers depend on the mathematical sciences and need a sound foundation in the discipline of mathematics to succeed. For the average citizen, grounding in mathematics, at least up to the secondary level, is essential to modern citizenship. Innumeracy is as crippling as illiteracy (Mathematical Association of America, 1998). The mathematical sciences – and all other sciences – are performed in a world that is changing rapidly.

The present study was undertaken in two phases to examine the effectiveness of using hands-on activities in mathematics in terms of the classroom learning environment, achievement, and attitudes among Grades 4 and 5 students. It was conducted in predominantly Hispanic communities in the Miami-Dade County Public Schools (MDCPS) district, Florida, United States of America. This chapter describes the background of this study (Section 1.2), the purposes of the study (1.3), and the organization of the chapters for the remainder of the thesis (Section 1.4).

1.2 Background of the Study

This section provides background information that is relevant to the study. It gives a brief introduction to the field of learning environments (Section 1.2.1), an overview of some of the challenges faced by the education system in the State of Florida (Section 1.2.2), a description of teaching and learning in the State of Florida, and problems faced by teachers in the Miami-Dade County Public Schools (MDCPS) district where the present study took place (Section 1.2.4).

1.2.1 Field of Learning Environments

International research efforts involving the conceptualization, assessment, and investigation of perceptions of aspects of the classroom environment have firmly established classroom environment as a thriving field of study (Fraser, 1998, 2002; Fraser & Walberg, 1991). For example, recent classroom environment research has focused on constructivist classroom environments (Aldridge, Fraser, Taylor, & Chen, 2000; Taylor, Dawson, & Fraser, 1995), computer-assisted instruction classroom (Teh & Fraser, 1994), and teacher interpersonal behavior in the classroom (Wubbels, Creton, Levy, & Hooymayers, 1993; Kent & Fisher, 1997). Classroom environment instruments have been used as sources of predictor and criterion variables in a variety of research studies. Use of student perceptions of actual classroom environment as independent variables in several different countries has established relationships between the nature of the classroom environment and various student cognitive and affective outcomes (Fraser, 1986; Fraser & Fisher, 1982; Haertel, Walberg & Haertel, 1981). Research involving a person-environment fit perspective has shown that students achieve better where there is greater congruence between the actual classroom environment and that preferred by students (Fraser & Fisher, 1983). The combination of qualitative and quantitative methods has been a feature of several recent learning environment studies (Fraser & Tobin, 1981; Tobin & Fraser, 1998).

From as early as 1936, Kurt Lewin (1936) recognized that the environment is a determinant of human behavior. Following Lewin's work, Murray (1938) proposed a Needs-Press Model in which situational variables found in the environment account for a degree of behavioral variance. Foundations for classroom environment research were laid when the work of Lewin and Murray assumed particular significance. Lewin (1936) introduced the formula $B=f(P, E)$ to describe human behavior (B) as a function of two interdependent influences, the Person (P) and the Environment (E). Murray (1938) developed this theory to describe the concept of the personal needs of an individual (including goals and drives) and the environmental press (including stimulus, treatment, and process variables). Murray's needs-press theories led to the development of various measures that rarely were considered in early studies.

Building on the work of Lewin and Murray, two research programs embarked on developing instruments that could be used to assess classroom learning environments. Herbert Walberg's *Learning Environment Inventory* (Anderson & Walberg, 1968) and Rudolf Moos's *Classroom Environment Scale* (Moos & Houts, 1968; Moos & Trickett, 1974) were the first instruments developed to assess students' perceptions of their learning environment, and these paved the way for the development of many subsequent instruments.

In the past three decades, much attention has been given to the development and use of instruments for assessing the quality of classroom learning environments from the perspective of the students (Fraser, 1986, 1994, 1998a; Fraser & Walberg, 1991). As well, the association between learning environment variables and student outcomes has provided a particular rationale and focus for the use of learning environment instruments. Walberg's theory of educational productivity (Walberg, 1981, 1984) holds that there are nine factors which contribute to variance in students' cognitive and affective outcomes: student ability, age and motivation; the quality and quantity of instruction; and the psychological climate of the home, the classroom social group, the peer group outside the classroom, and the mass media (especially television viewing). Tests of this model of educational productivity attest to the importance of the learning environment, among a set of other factors, in co-determining student outcomes (Fraser, Walberg, Welch & Hattie, 1987).

Studies involving the use of the actual form of the classroom environment scales as criterion variables have revealed that classroom psychosocial climate varies between different types of schools (Trickett, 1978) and between coeducational and single-sex schools (Trickett et al., 1982). Both researchers and teachers have found it useful to employ classroom climate dimensions as process criteria of effectiveness in curriculum evaluation because they have differentiated revealing between alternative curricula when student outcome measures have shown little sensitivity (Fraser, Williamson & Tobin, 1987; Maor & Fraser, 1996; Teh & Fraser, 1994).

Research in the USA (Moos, 1979), Australia (Fisher & Fraser, 1983), and The Netherlands (Wubbels et al., 1991) compared students' and teachers' perceptions and found that, first, both students and teachers prefer a more positive classroom environment than that perceived as being actually present and, second, teachers tend to perceive the classroom environment more positively than do their students in the same classrooms. In promising small-scale practical applications, teachers have used assessments of their students' perceptions of their actual and preferred classroom environment as a basis for identification and discussion of actual-preferred discrepancies, followed by a systematic attempt to improve classrooms (Fraser & Fisher, 1986; Thorp, Burden & Fraser, 1994; Yarrow, Millwater & Fraser, 1997).

Past studies of interpersonal teacher behavior have indicated that this important element of the learning environment is strongly related to student outcomes. A study conducted among Australian science and mathematics teachers found that those teachers emphasizing leadership, friendly and understanding behaviors were more likely to promote student achievement. It also was found that those teachers who were perceived as less strict were more likely to promote positive attitudes, whilst those who were perceived as more strict were likely to promote better achievement (Wubbels, 1993). To measure students' and teachers' perceptions of teachers' interpersonal behavior, Wubbels and his colleagues developed the Questionnaire on Teacher Interaction (QTI). This instrument is one of several selected for use in my study because it has been used extensively and successfully in The Netherlands (Wubbels, Brekelmans & Hooymayers, 1991), Singapore (Goh & Fraser, 1995), Australia (Fisher, Henderson, & Fraser; 1995; Henderson, Fisher & Fraser, 1995) and other countries (Fraser, 2002). In each case, the studies have found that the quality of the interaction between teachers and students is an important determinant of students' achievement and attitudes. The study of interpersonal teacher behavior is important not only for facilitating student outcomes, but also for improving teacher competency in classroom communication and for providing the social and emotional backup that a teacher needs to reach out to students.

This area in classroom environment research, involving the Questionnaire on Teacher Interaction (QTI), has focused mainly on secondary science and mathematics classes in The Netherlands, the United States and Australia, with some recent noteworthy studies having been undertaken in Asian countries (Goh & Khine, 2002). It was considered interesting and timely to extend the area of study from secondary to elementary classrooms in Miami-Dade County, Florida, United States of America.

Historically, researchers have focused on students' outcomes in the cognitive domain; but the study of student attitudes formed a primary component of my research (Weinburgh, 1995). Shulman and Tamir (1972) suggested that the affective outcomes of education are at least as important as cognitive outcomes, and the importance of affective outcomes is reflected in their increasing emphasis in curricula (Gardner & Gauld, 1990; Hough & Piper, 1982; Matthews, 1974). Several studies investigated attitude as one of the student outcome measures to be related to classroom environment. However, the majority of these studies focused specifically on science-related attitudes. Many studies have shown positive relationships between the students' attitude toward science and classroom environments (Adolphe, Fraser & Aldridge, 2002; Fraser & Butts, 1982).

1.2.2 Challenges Facing the Education System in Florida

For the 21st century, the State of Florida faces numerous challenges. Foremost among them, are the challenges to provide all children in the State with a high-quality education, and to revitalize and transform all of its public schools into centers of academic excellence. Florida's children and youth are its future and most precious resource. Therefore, it is no wonder that Florida's citizens are passionate about education, which is the institution that most directly affects the future. Public education, then, must continue to be the State's top priority.

According to data published by the National Center for Education Statistics (NCES), Florida's public elementary schools have the highest average enrollment in the nation (U.S Department of Education, NCES Digest of Education Statistics, 1999). In the Fall of 2001, total Grade pre-K–12 student enrollments were 2,495,426 for Florida's 67 school districts. Growth in student population has continued for the eighteenth consecutive year. Representation by each racial/ethnic group in the total pre-K–12 grade enrollments for the Fall 2001 were 51.38% white non-Hispanic, 24.52% Black non-Hispanic, 20.20% Hispanic, 1.92% Asian/Pacific Islander, 1.70% multiracial, and 0.28% American Indian/Alaskan Native. Total minority representation is 48.62% of the total pre-K–12 enrollment (Florida Department of Education, June 2002).

Other major problems in public school education in the State of Florida include overcrowding, especially in the larger and more diverse school districts, and the lack of properly-trained subject area teachers. Elementary teachers have to teach the entire core subjects to their students and some have limited background knowledge in mathematics and science. In the middle schools, teachers usually teach within their area of expertise. However, with the lack of properly-trained subject area teachers, content knowledge is lacking, and this can lead to poor academic performance among students.

1.2.3 Teaching and Learning in Florida: Manipulatives

Since the inception of the Florida Comprehensive Assessment Test (FCAT) in 1998, school systems within the state have sought ways of improving teachers' teaching and students' learning. They have developed new understandings and skills informed by recent research about teaching, learning, and assisting peers in improving their teaching and learning. Learning about recent research and translating it into practice is the centrepiece of the cooperative relationship among state universities, school districts, and teachers' unions.

There are numerous long-term projects to develop new approaches that include a wide range of topics and methods. Constructivist approaches to teaching and learning have been introduced in school districts. Ideas about how to learn to listen to students' thinking, how to organize classroom activities to support listening and questioning, and how to implement forms of assessment that document children's questions, as suggested by Maher and Alston (1990), are being implemented by school districts. Teachers and curriculum planners within the state are working collaboratively to develop skills of working together to provide programs that will enhance student achievement. To help teachers to experience the change process, programs with strong emphasis on analysis and improvement of their teaching and learning are ongoing. Teachers are learning skills in working together with peers, observing teaching methods and giving feedback, as well as in how to assist peers in changing their teaching. School districts within the state offer a broad range of programs in curriculum and teaching in order to prepare exemplary teachers and teacher educators and to ensure higher achievement by students on standardized tests.

One of the innovative teaching approaches frequently used in mathematics in MDCPS involves the uses of ‘manipulatives’. Mathematical manipulatives are concrete, hands-on models that appeal to the senses and can be touched by students. Manipulatives are any materials or objects from the real world that illustrate mathematics concepts. It is very important that students become familiar with the items and make observations. Students should be given the opportunity in elementary schools to explore, describe, investigate, record, share, question and talk about what they discover. Research in England, Japan, China, and the United States supports the idea that mathematics instruction and student mathematics are likely to be more effective if manipulative materials are used (Heddens, 1986).

1.3 Purposes of the Study

A main purpose of the present study was to provide important insights into the field of learning environments at the elementary school level in a diverse school community within the Miami-Dade County Public Schools (MDCPS) district. The overall purpose of the study was to determine if the use of hands-on manipulatives promotes improvements in classroom environment, attitudes to mathematics, and achievement among selected fourth and fifth grade students in a Miami-Dade County elementary school in Florida, USA. This research project also investigated associations between the classroom environment and students’ attitudes toward and achievement in mathematics.

The study made use of a teacher-made multiple-choice mathematics test patterned after the Florida Comprehensive Assessment Test (FCAT). Also various learning environment questionnaires were administered to participants of the study in conjunction with scales assessing students' attitudes to mathematics.

The present study is likely to provide valuable information to the administrators and teachers at the schools where the data were gathered for use in developing strategies for improving classroom practices in the area of mathematics. The results of the study could also provide guidance to other elementary schools with similar diverse population in the school district regarding achieving improved student outcomes in mathematics.

To measure students' achievement in mathematics, a multiple-choice mathematics test was designed and administered. To measure students' perceptions of learning environment, the My Class Inventory (MCI), the Science Laboratory Environment Inventory (SLEI), and the Questionnaire on Teacher Interaction (QTI) were administered in Phase 1. The scales were modified, item wording was simplified to enhance readability, and scales were shortened because students were of Hispanic heritage and most of them were learning English as a second language. For Phase 2 of the study, the What Is Happening In this Class? (WIHIC) was used to assess classroom environment. The Test Of Mathematics-Related Attitudes (TOMRA), modified from the Test Of Science-Related Attitudes (TOSRA), was utilized to assess student attitudes.

Specifically, the present study addressed the following three main research questions:

1. Is it possible to develop and validate suitable measures of:
    a) classroom environment
    b) students' attitudes toward mathematics?

2. Is the use of hands-on manipulatives effective in providing improvements in:
    c) students' achievement in mathematics
    b) students' attitudes toward mathematics
    a) classroom environment?

3. Are there relationships between classroom environment and:
    b) students' achievement in mathematics
    a) students' attitudes toward mathematics?

1.4 Organization of the Thesis

This thesis comprises five chapters. The first chapter discusses the rationale for the present study. It provides a brief background to the study, including information about the field of learning environments, challenges facing the education system in Florida and teaching and learning in Florida where the study took place. The chapter also discusses the purposes of the present study, gives an outline of the research questions and provides an overview of the organization of the thesis.

Chapter 2 reviews the literature and related research pertaining to achievement, learning environment and attitudes. In particular, it highlights past research developments and findings in the field of classroom learning environments. Also, this chapter reviews literature on interpersonal teacher behaviour and attitudes in terms of existing assessment instruments.

Chapter 3 discusses methodology and provides insights into procedural aspects of the present study. This includes the research design used in the different phases of the study, the choice of learning environment and attitude instruments, and the choice of the samples for this study. Discussed in this chapter too is the administration of the questionnaires and data collection, as well as the statistical procedures employed in the data analysis.

Chapter 4 reports the data analysis and findings for the present study. Results are presented for the reliability and validity of environment and attitude scales, including factor structure, internal consistency reliability, and the ability of classroom environment scales to differentiate between the perceptions of students in different classes. It also reports results about the effectiveness of the use of manipulatives in terms of classroom environment, attitudes and in achievement. Finally the chapter reports findings regarding associations between student outcomes (attitudes and achievement) and classroom environment.

Chapter 5 provides a summary of the entire thesis. In particular, it summarises the findings from the study for the research questions about the validation of each assessment instrument, the effectiveness of using hands-on activities in mathematics in terms of learning environment, attitudes and achievement, and associations between student outcomes (attitudes and achievement) and classroom environment.

Chapter 6 concludes the thesis with a discussion of numerous salient issues. For example, this chapter discusses the reasons for conducting the study in two phases and the anomalous findings for attitude-environment associations. As well, it also discusses the practical implications of the findings from the study, the significance of the study, some limitations to the present study, and suggestions for further research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The present study focused on the effectiveness of using hands-on mathematics activities in terms of learning environment, achievement, and attitudes in Grades 4 and 5 in five elementary schools in the diverse Miami-Dade County Public Schools (MDCPS) district. Since 1998, the State of Florida and the Miami-Dade County Public Schools (MDCPS) district has embarked on a quest to improve all students' scores on achievement tests. This was instigated partly because of the State's low achievement results on the Third International Mathematics and Science Study (TIMSS, 1997). The State of Florida developed a performance-based assessment, the Florida Comprehensive Assessment Test (FCAT), to assess student achievement of higher-order cognitive skills represented in the Sunshine State Standards (SSS). This test is administered to students in Grades 3 to 10 in the spring of each year in mathematics, science, and reading.

This chapter reviews literature relevant to the present study. Section 2.2 focuses on background information about learning environments, whereas Section 2.3 provides a historical perspective on the field of learning environment. Section 2.4 looks at various methods for assessing classroom learning environment research. Section 2.5 discusses the unit of analysis issue, whereas Section 2.6 reviews instruments for assessing classroom environment. Section 2.7 reviews past studies into associations between student outcomes and classroom environment. Section 2.8 reviews other applications of learning environment instruments in past research and Section 2.9 reviews studies carried out in Asia. Finally, Section 2.10 gives a summary of the chapter.

The structure of this literature is summarized below:

2.2 Background Issues

The word ‘environment’ has many meanings. It can be described as the shared perceptions of the students and sometimes teachers in the classroom (Fraser, 1986). But, broadly there are two aspects of the classroom environment: the human and physical environment. The human environment includes the students and teachers in a classroom and their interaction with one another, while the physical environment includes the material and setting, including furniture, lighting, and how furniture and objects are laid out in the classroom. The human environment encompasses how the teacher facilitates learning and plays an important part in making it more conducive to learning for all students. Brophy and Putnam (1979) have shown in past studies that effective learning is related to a positive classroom environment.

Research has traditionally focused on variables like intelligence and achievement but, over the past 40 years, researchers have begun to move their attention to other important variables, such as the learning environment, which also can impact on student outcomes. Over this period, there has been much interest in the study of the concept classroom learning environment. Although the concept of classroom learning environment is somewhat subtle and nebulous according to Fraser (1989), remarkable progress has been made to date in terms of conceptualizing it, measuring it and analyzing its determinants and effects (Fraser, 1993). Fraser (1986) defined classroom environment as the shared perceptions of students and sometimes those of teachers in a particular environment, and claimed that such perceptions not only evaluate or describe the class through the eyes of the participants themselves, but include information that an observer could miss or consider unimportant.

Classroom learning environment studies really began to attract attention from the late 1960s, with the work of Walberg and Anderson (1968a, 1968b) in connection with the research and evaluation related to Harvard Project Physics, as well as Moos' research related to social climate scales for use in various clinical and family therapy situations as well as school classrooms (Moos, 1973, 1979a, 1979b). From as early as the late1960s and early 1970s, Moos and Walberg pioneered many research projects into perceptions of classroom environments. From then on, there emerged a distinct tradition of research on students' perceptions of their classroom environment (Fraser

& Walberg, 1981) which is described in reviews of the field of learning environments (e.g. Anderson & Walberg, 1974; Chavez, 1984; Fraser, 1989, 1994, 1998a, 2002; von Saldern, 1992; Walberg, 1976; Walberg & Haertel, 1980), monographs (Fisher, 1992, 1993; Fisher & Fraser, 1983a; Fraser, 1981), guest-edited journal issues (Fraser, 1980; McRobbie & Ellett, 1997), an annotated bibliography (e.g. Moos & Spinrad, 1984), books (Fraser 1986; Fraser & Walberg, 1991; Goh & Khine, 2002; Moos, 1979a; Walberg, 1979; Wubbels & Levy, 1993) and in the editor's introduction to a new international journal entitled *Learning Environments Research* (Fraser, 1998b).

The concept of attitude, its definition and its measurement have been widely explored in books such as Eiser (1984), Mueller (1986) and Lemon (1973). According to Mueller (1986), attitudes cannot be observed or measured directly. There existence must be inferred from their consequences. Given that an attitude is non-observable psychological construct whose presence can only be deduced from the behavior manifested, it is thus not surprising that there is no unanimous agreement amongst social scientists on any given definition for the term attitude. Furthermore, the definition of the term could undergo modification with the passage of time as new light is thrown by attitude-related research. Thurstone, (1928), the social psychologist who first formulated and popularised the methodology for measuring attitude, defined it as the sum total of a person's inclinations and feelings prejudice and bias, preconceived notions, ideas, fears, threats and convections about any specified topics. He later modified the definition of attitude to "the effect for or against a psychological object" (Thurstone, 1931). However, Thurstone (1946) later commented that he wished that he had kept to his draft definition of attitude in his

1928 paper, as this was a narrower definition. According to Allport (1935), however, attitude is a mental or neutral state of readiness. Linton (1945) comments that attitude is the covert response evoked by a value.

The notion attitudinal behavior is learned and could be further modified is widely accepted by social scientists. Also, acknowledged by researchers and educators are the relationships of attitudes to values and beliefs and hence its impact on the human psyche.

2.3 Historical Background to the Field of Learning Environment

The concept of learning environment has taken root since the 1930s especially with the emergence of Murray's needs-press model (1938) and Lewin's social-psychological work (1936), which recognized that behavior is a function of the person and the environment. In 1960, a framework for the analysis of the classroom group as a unique social system was developed by Getzels and Thelen (1960). Stern (1970) formulated a theory of person-environment congruence in which complementary combinations of personal needs and environmental press enhance student outcomes. Later, Doyle (1979) proposed that the classroom environment be viewed from an ecological viewpoint, placing strong emphasis on inter-relationships and communications among all members in the classroom community. Learning environment refers to the social, physical, psychological, and pedagogical context in which learning occurs and which affects student achievement and attitudes (Fraser, 2000). McRobbie (2002) states that the majority of research on classroom environments has focused on characterizing the learning environment in classrooms rather than in monitoring changes to class or individual student perceptions of the learning environments as a consequence of interventions.

A historical look at the field of learning environment over the past few decades shows that an important feature is the availability of a variety of valid, economical and widely-applicable questionnaires that have been developed and used for measuring students' perceptions of classroom environment. Past research has used learning environment questionnaires in curriculum evaluation (Fraser, 1979), in investigating the effects of environment on student learning (McRobbie & Fraser, 1993a), in studies of differences between students' and the teacher's perceptions of the same classroom (Fisher & Fraser, 1983b), research on the transition from primary to secondary school (Ferguson & Fraser, 1998), teachers' practical attempts to improve classroom learning environments (Thorp, Burden, & Fraser, 1994), and the use of learning environment ideas in school psychology (Burden & Fraser, 1993).

Because some dimensions are more salient than others in a particular classroom, the decision to use specific learning environment scales in a classroom ideally should take place after researchers have had some experience in the class. With the wide variety of learning environment questionnaires available, it is possible to identify numerous existing scales that have potential significance to a given classroom. What is regarded as salient by different participants in a community might differ depending on roles, goals and theoretical framework. Therefore, the selection of scales to include in a learning environment study depends on whose perspectives are considered more important in the research. Although much research has been conducted on student perceptions of classroom learning environment, surprisingly, little has been done to help mathematics teachers assess and improve the environment of their own classrooms.

2.4 Methods for Assessing Learning Environment

The dominant past approach in research on classroom environment has been the use of perceptions of students and teachers in evaluating the learning environment. However, it is now widely acknowledged that there are merits in combining two or more methods in a study (Fraser & Tobin, 1991; Tobin & Fraser, 1998). There are three main methodologies used in classroom environment research: the use of trained observers to record observations of classroom practices and events, the assessment of perceptions, and the use of case studies.

(Fraser, 1993a) points out five main considerations in justifying the use of perceptual measures. First, the use of questionnaires to capture perceptions of students and teachers is more economical than the process of having trained observers making the observations. Second, data from such measures are based on the perceptions of students over many lessons or a long period of time, while classroom observations are limited usually to a small number of lessons. Third, perceptual measures bring together the pooled opinions of all students in a class whereas classroom observations generally involve the perceptions of only one observer. Fourth, student perceptions account for considerably more variance in student learning outcomes than do directly-observed variables in classrooms. Fifth, student perceptions are the determinants of student behavior more so than the 'real' situation, and so can be more important than observed behaviours. The present study used data based on measures of student perceptions of learning environments over a period of time, in conjunction with the observation of students in their classroom environments.

Despite the fact that the original forms of several instruments measuring student perceptions of classroom environment have proved useful for various research purposes, experience have shown that many teachers would prefer an assessment method which is more economical in terms of the time required for administration and scoring. As a result, a short version of several classroom environment questionnaires was developed to satisfy two main criteria (Fraser & Fisher, 1983c). First the number of items was reduced to provide greater economy in testing and scoring time. Second, because many teachers do not have ready access to computerized scoring methods, the short form was designed to be amendable to easy hand scoring.

2.5 Choosing Units of Analysis

A growing body of literature acknowledges the importance and consequences of the choice of level or unit of statistical analysis and considers the hierarchical analysis and multilevel analysis of data (Bock, 1989; Bryk & Raudenbush, 1992; Goldstein, 1987). The choice of unit of analysis is important because measures having the same operational definition can have different interpretations with different levels of aggregation, and relationships obtained using one unit of analysis can differ in magnitude and even in sign from relationships obtained using another unit. It is apparent from current literature that research on learning environments often uses two units of statistical analysis.

Murray's distinction between alpha press (the environment as observed by an external observer) and beta press (the environment as perceived by milieu inhabitants) has been extended by Stern, Stein, and Bloom (1956) to distinguish between 'private beta press' (to denote the idiosyncratic view of the environment held by each individual) and 'consensual beta press' (to depict the shared view that members of a group hold about the environment). Private and consensual beta press could differ from each other and they could both differ from the detached view of alpha press of a trained non-participant observer. Therefore, in designing classroom environment studies, an important dimension is whether to use individual students' perceptions (private press) or whether these will combined to obtain the average of the environment scores of all students within the same class (consensual press).

In the present study, I followed the convention often used in past classroom learning environment research of conducting several of the statistical analyses for two units of analysis, namely, the individual student and the class mean.

2.6 Instruments Used for Measuring Classroom Learning Environment

This section is devoted to a review of existing instruments for assessing perceptions of classroom learning environments. The instruments reviewed are the Learning Environment Inventory (LEI), Classroom Environment Scale (CES), Individualized Classroom Environment Questionnaire (ICEQ), My Class Inventory (MCI), College and University Classroom Environment Inventory (CUCEI), Questionnaire on Teacher Interaction (QTI), Science Laboratory Environment Instrument (SLEI), and Constructivist Learning Environment Survey (CLES), and What Is Happening in this

Class? (WIHIC) questionnaire. These instruments are all convenient paper-and-pencil questionnaires which can be scored effectively either by hand or by computer. Each instrument has its unique origin and caters for different purposes and backgrounds. The following sections briefly describe each of the instruments in turn.

2.6.1 Learning Environment Inventory (LEI)

The initial development and validation of a preliminary version of the Learning Environment Inventory (LEI) began in the late 1960s in conjunction with the evaluation and research related to the Harvard Project Physics (Fraser, Anderson & Walberg, 1982; Walberg & Anderson, 1968a). The final version contains a total of 105 statements (or seven per scale). Students respond using the four-point Likert response scale of Strongly Disagree, Disagree, Agree, and Strongly Agree.

2.6.2 Classroom Environment Scale (CES)

The Classroom Environment Scale (CES) was developed by Rudolf Moos at Stanford University (Fisher & Fraser, 1983c; Moos, 1979a; Moos & Trickett, 1974, 1987) and grew out of a comprehensive program of research involving perpetual measures of a variety of human environments including psychiatric hospitals, prisons, university residencies and work milieus (Moos, 1974). The final published version contains nine scales with 10 items of True/False response format. The CES is published with a test manual, a questionnaire, an answer sheet and a transparent hand-scoring key (Moos & Trickett, 1987).

TABLE 2.1 Overview of Scales Contained in Nine Classroom Environment Instruments (LEI, CES, ICEQ, MCI, CUCEI, QTI, SLEI, CLES, and WIHIC)

			Moos's Classification		
Instrument	Level	Items per Scale	Relationship Dimensions	Personal Development Dimensions	Systems Maintenance and Change Dimensions
Learning Environment Inventory (LEI)	Secondary	7	Cohesiveness Friction Favouritism Cliqueness Satisfaction Apathy	Speed Difficulty Competitiveness	Diversity Formality Material Environment Goal Direction Disorganization Democracy
Classroom Environment Scale (CES)	Secondary	10	Involvement Affiliation Teacher Support	Task Orientation Competition	Order and Organization Rule Clarity Teacher Control Innovation
Individualized Classroom Environment Questionnaire (ICEQ)	Secondary	10	Personalization Participation	Independence Investigation	Differentiation
My Class Inventory (MCI)	Elementary	6–9	Cohesiveness Friction Satisfaction	Difficulty Competitiveness	
College and University Classroom Environment Inventory (CUCEI)	Higher Education	7	Personalization Involvement Student Cohesiveness Satisfaction	Task Orientation	Innovation Individualization
Questionnaire on Teacher Interaction (QTI)	Secondary/ Primary	8–10	Leadership Helpful/Friendly Understanding Student Responsibility/ Freedom Uncertain Dissatisfied Admonishing Strict		
Science Laboratory Environment Inventory (SLEI)	Upper Secondary/ Higher Education		Student Cohesiveness	Open-endedness Integration	Rule Clarity Material Environment
Constructivist Learning Environment Survey (CLES)	Secondary	7	Personal Relevance Uncertainty	Critical Voice Scared Control	Student Negotiation
What Is Happening In this Class? (WIHIC)	Secondary	8	Student Cohesiveness Teacher Support Involvement	Investigation Task Orientation Cooperation	Equity

Based on Fraser (1998b).

2.6.3 Individualized Classroom Environment Questionnaire (ICEQ)

The Individualized Classroom Environment Questionnaire (ICEQ) assesses those dimensions which distinguish individualized classrooms from conventional ones. The initial development of the ICEQ (Rentoul & Fraser, 1979) was guided by the literature on open and inquiry-based education, extensive interviewing of teachers and secondary school students, and reactions to draft versions sought from selected experts, teachers and junior high school students. It assesses 'individualized' dimensions in the secondary classroom, such as participation and personalization (Fraser, 1990; Rentoul & Fraser, 1979). The final published version of the ICEQ (Fraser, 1990) contains 50 items altogether with an equal number of items in each of the five scales. However, the ICEQ also has a short 25 item version. Each item is responded to on a five-point scale with the alternatives of Almost Never, Seldom, Sometimes, Often, and Very Often. The scoring direction is reversed for many of the items. The scales are Personalization, Participation, Independence, Investigation, and Differentiation.

2.6.4 My Class Inventory (MCI)

The Learning Environment Inventory (LEI) was simplified to form the My Classroom Inventory (MCI) for use among children aged 8–12 years (Fisher & Fraser, 1981; Fraser, Anderson, & Walberg, 1982; Fraser & O'Brien, 1985; Majeed, Aldridge, & Fraser, 2002). Although the MCI was developed for the elementary school level, it could also be used with students in junior high school or middle schools, especially those who might experience reading difficulties with other instruments. The MCI differs from the LEI in four important ways. First, in order to minimize fatigue among younger students, the MCI contains only five of the LEI's original 15 scales. Second, item wording has been simplified to enhance readability. Third, the LEI's four-point response format has been reduced to a two-point (Yes/No) response format. Fourth, students answer on the questionnaire itself instead of on a separate sheet to avoid errors in transferring responses from one place to another. The final form of the MCI contains 38 items altogether. Although the MCI traditionally has been used with a Yes/No response format, Goh, Young, and Fraser (1995) have successfully used a three-point response format (Seldom, Sometimes, and Most of the Time) with a modified version of the MCI which includes a Task Orientation scale.

2.6.5 College and University Classroom Environment Inventory (CUCEI)

The College and University Classroom Environment Inventory (CUCEI) was developed to fill a void for an instrument assessing learning environment at the higher education level. The CECUI was developed for use in small classes, sometimes referred to as 'seminars' (Fraser & Treagust, 1986; Fraser, Treagust, & Dennis, 1986). Each item has four responses (Strongly Agree, Agree, Disagree, and Strongly Disagree). Research shows that using the CUCEI parallels, the effort at assessing learning environments in secondary and elementary schools at the tertiary level.

2.6.6 Questionnaire on Teacher Interaction (QTI)

The Questionnaire on Teacher Interaction (QTI) was developed specially for evaluating teacher-student relationships in secondary schools (Wubbels, Brekelmans & Hooymayers, 1991; Wubbels & Levy, 1993). The QTI assesses student perceptions of eight behavior aspects. Each item has a five-point response scale ranging from Never to Always. The QTI was originally an instrument in the Dutch language developed for use in a teacher education project at the University of Utrecht, Holland. It focuses on the nature and quality of interpersonal relationships between teachers and students (Creton, Hermans & Wubbels 1990; Wubbels, Brekelman, & Hooymeyers, 1991; Wubbels & Levy, 1993). Later, an English version was used in the United States (Wubbels & Levy, 1991).

Interpersonal teacher behavior is mapped using eight scales circumrotating on the two axes of influence (dominance, submission) and proximity (cooperation, opposition). The eight scales of teacher interaction behavior (Leadership, Understanding, Helping/Friendly, Student Responsibility/Freedom, Uncertain, Dissatisfied, Admonishing and Strict behavior) fall naturally within Moos's (1974) category of relationship dimensions. The QTI has been used in several large-scale studies in Asia. Goh pioneered the use of the QTI in a simplified form in Singapore with a sample of 1512 primary mathematics students in 39 classes in 13 schools (Goh & Fraser, 1996, 1998, 2000.) Fisher, Goh, Wong and Rickards' (1997) used the QTI in Singapore with 20 secondary science classes. Scott and Fisher translated the QTI into standard Malay and cross-validated it with 3104 primary school students in 136 classes in Brunei Darussalam. An English version of the QTI has been cross-validated for secondary schools in Brunei Darussalam (Khine & Fisher, 2002) and in Korea (Kim, Fisher, & Fraser 2000; Lee & Fraser, 2001a, 2003) and in Indonesia (Soerjaningsih, Fraser & Aldridge, 2001b).

Because the quality of interpersonal interactions between the teacher and student is such an important aspect of the classroom learning environment, Wubbels and Levy (1993) initiated a major program of research in this area. This work on teacher interpersonal behavior which formed an important thrust in my study, is discussed next. A systems approach to communication was inspired by the theory of Watzlawick (1967). It was adapted to the educational setting to describe teacher behavior within the classroom setting (Wubbels, 1988; Wubbels & Brekelmans, 1998; Wubbels & Levy, 1993). According to Creton (1993), systems communication theory is underpinned by the interdependent relationship of circularity and change. Circularity refers to the inter-relatedness of all aspects of the communication system; changes in one aspect affect changes to another (Creton, 1993). Therefore, in the classroom setting, the behavior of the teacher determines and is determined by the behavior of the students (Wubbels, 1991).

2.6.7 Science Laboratory Environment Inventory (SLEI)

The Science Laboratory Environment Inventory (SLEI) is an instrument specifically designed for assessing the environment of science laboratory classes at the senior high school or higher education levels (Fraser, Giddings, & McRobbie, 1995; Fraser & McRobbie, 1995; Fraser, McRobbie & Giddings, 1993). The SLEI has five scales (each with seven items) and the five frequency response alternatives are Almost

Never, Seldom, Sometimes, Often and Very Often. The five scales are Student Cohesiveness, Open-Endedness, Investigation, Rule Clarity, and Material Environment. The Open-Endedness scale was added because of the importance of open-ended science laboratory activities. The SLEI was field-tested and validated simultaneously with a sample of over 5,447 students in 269 classes in six different countries (the USA, Canada, England, Israel, Australia, and Nigeria). It was cross-validated with 1,594 Australian students in 92 classes (Fraser, & McRobbie, 1995), with 489 senior high school biology students in Australia (Fisher, Henderson & Fraser, 1997), and with in Singapore with samples of 1592 grade 10 chemistry students (Wong & Fraser, 1995), and 497 gifted and non-gifted chemistry students (Quek, Fraser, & Wong, 2001; Quek, Wong & Fraser, 2005). Riah and Fraser (1998) cross-validated the English version of the SLEI with 644 Grade 10 chemistry students in Brunei Darussalem. Another noteworthy program of research involving a Korean-language version of the SLEI has been initiated by Kim and built upon by Lee (Kim & Kim, 1995, 1996; Kim & Lee, 1997; Lee & Fraser, 2001b, 2003).

2.6.8 Constructivist Learning Environment Survey (CLES)

The Constructivist Learning Environment Survey (CLES) was developed to assist researchers and teachers to assess the degree to which a particular classroom's environment is consistent with a constructivist epistemology, and to assist teachers to reflect on their epistemological assumptions and to reshape their teaching practice. The CLES is based on three principles of constructivism: learning as a construction of knowledge; that knowledge is constructed inter-subjectively; and that the learner is an interactive co-constructor of scientific knowledge (Taylor, Dawson & Fraser, 1995; Taylor, Fraser & Fisher, 1993, 1997; Taylor, Fraser & White, 1994). The CLES contains five scales (Personal Relevance, Uncertainty, Critical Voice, Shared Control, and Student Negotiation), with seven items per scale. It uses the response alternatives of Very Often, Often, Sometimes, Seldom or Never.

A Korean-language version of the Constructivist Learning Environment Survey (CLES) has been validated with 1,083 students in high school science classes in Korea (Kim, Fisher & Fraser, 1999). It also has been validated with 1,081 students from 50 classes in Australia and, using a Chinese-language version, with 1,879 students from 50 classes in Taiwan (Aldridge, Fraser Taylor & Chen, 2000). The CLES also has been used successfully in South Africa (Sebela, Fraser, & Aldridge 2003) and in several studies in the USA (Dryden & Fraser, 1998; Johnson & McClure, 2002; Nix, Fraser & Ledbetter, 2003, 2005).

2.6.9 What Is Happening In this Class? (WIHIC) Questionnaire

The WIHIC questionnaire brings parsimony to the field of learning environments by combining modified versions of the most salient scales from a wide range of existing questionnaires with additional scales that accommodate contemporary educational concerns (e.g. equity and constructivism) (Fraser, Fisher, & McRobbie, 1996). The final version of the WIHIC questionnaire containing seven eight-item scales, namely, Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation and Equity. It has been used successfully in studies in numerous countries including Australia and Taiwan (Aldridge & Fraser, 2000; Aldridge, Fraser & Huang, 1999), Australia, Canada and England (Dorman, 2003), Singapore (Chionh & Fraser, 1998, Fraser & Chionh, 2000; Khoo & Fraser, 1997), Brunei (Riah & Fraser, 1998) Canada (Raaflaub & Fraser, 2002; Zandvliet & Fraser, 1998, 2004, 2005), Indonesia (Margianti, Fraser & Aldridge, 2002) and Korea (Kim, Fisher & Fraser, 2000). A modified version of the WIHIC questionnaire was used in my study, and is discussed in more detail in Chapter 3. Dorman (2003) used confirmatory factor analysis with data on the WIHIC from 3980 high school students in Australia, Canada and the USA.

2.7 Associations Between Classroom Environment and Student Outcomes

The strongest tradition in past classroom environment research has involved investigation of associations between students' cognitive and affective learning outcomes and perceptions of psychosocial characteristics of their classrooms (Fraser & Fisher, 1982c; Haertel, Walberg & Haertel, 1981; McRobbie & Fraser, 1993). As one of my study's research question also focused on outcome-environment associations, this line of past research is reviewed in this section. Numerous research programs have shown those students' perceptions of their learning environment account for appreciable amounts of variance in learning outcomes, often beyond that attributable to background student characteristics. Fraser's (1994) tabulation of 40 studies in science education shows that associations between outcome measures and classroom environment perceptions have been replicated for a variety of cognitive and affective outcome measures, a variety of classroom environment instruments and a variety of samples (ranging across many countries and grade levels).

Numerous studies of associations between classroom environment and student outcomes involving different subjects, grade levels, and countries tend to support the link between the two types of variables. Fraser and Fisher (1982c), in a study conducted in Australia, recorded sizeable associations between student perceptions of classroom environment and student outcomes. Studies conducted in the Southeast Asia countries, like Indonesia (Fraser, 1985; Fraser, Pearse & Azmi, 1982; Margianti & Fraser, 2000, Paige, 1978, 1979), Singapore (Chionh & Fraser, 1998; Fraser & Chionh, 2000; Goh, Young & Fraser, 1995; Teh & Fraser, 1993, 1994; Wong & Fraser, 1994, 1996), Korea (Lee & Fraser, 2003; Kim, Fisher & Fraser, 2000), and Brunei (Riah, & Fraser, 1998; Scott & Fisher, 2001) replicated prior research in that the nature of the psychological and social climate of classrooms was found to be a determinant of student outcomes (Fraser, 2000, 2002).

Two studies of outcome-environment associations compared the results obtained from multiple regression analysis with those obtained from an analysis involving the hierarchical linear model (HLM). The multiple regression analysis was performed separately at the individual student level and also after data had been aggregated at the class level. In the Wong, Young and Fraser's (1997) study involving 1,592 grade 10 students in 56 chemistry classes in Singapore, associations were investigated between three student attitude measures and a modified version of the Science Laboratory Environment Inventory (SLEI). In Goh, Young and Fraser's (1995) study with 1, 512 grade 5 mathematics students in 39 classes in Singapore, scores on a modified version of the My Class Inventory (MCI) were related to student achievement and attitude. Most of the significant results from the multiple regression analyses were replicated in the HLM analyses, as well as being consistent in direction.

Other studies which have replicated positive associations between classroom environments and students' attitudes towards science include Keeves (1972), Manley (1977), Fraser and Fisher (1982a, 1982b, 1982c, 1983c), Haladyna, Olsen and Shaugnessy (1982), Schibeci and Riley (1983), Talton and Simpson (1986, 1987), Akindehin (1993), and Krynowsky (1988). However, earlier studies conducted by Anderson and Walberg (1968), in association with work with the Harvard Project Physics, found a substantial negative correlation between the classroom environment variable of stratification (the tendency for work in the class to be left to those most capable for the job) and students' attitude to physics.

Studies of interpersonal teacher behaviour show that it is an important aspect of the learning environment that strongly relates to students' outcomes. A study involving Australian science and mathematics teachers found that emphasizing leadership, friendly, and understanding behaviours is likely to promote students' outcomes. The teachers who were stricter were more likely to promote student achievement, while those who were less strict tended to promote more positive student attitudes (Wubbels, 1993). Another use of the Questionnaire on Teacher Interaction (QTI) in the Netherlands involved investigation of relationships between perceptions on QTI scales and student outcomes (Wubbels, Brekelmans & Hooymayers, 1991). Use of the QTI in senior biology classes (Fisher, Henderson & Fraser, 1995) established associations between student perceptions of interpersonal relationships with their teachers and three categories of student outcomes (student attitudes, achievement in written examinations, and performance on practical tests). Use of this questionnaire in different countries has established that the interaction between teachers and students is an important determinant of student achievement and attitudes (Goh & Fraser, 1995; Henderson, Fisher & Fraser, 1995; Wubbels, Brekelmans & Hooymayers, 1991).

Outcome-environment associations were found when the Individualized Classroom Environment Questionnaire (ICEQ) was translated into Indonesian (Paige 1978, 1979), and when the Learning Environment Inventory (LEI) was translated into Hindi for a study in India (Walberg, Singh & Rasher, 1977). Recently, studies of relationships between student outcomes and secondary classroom environments were completed in Brunei (Asghar & Fraser, 1995; Riah & Fraser, 1998; Majeed, Fraser & Aldridge, 2002). Studies of learning environment have also been carried out in Singapore at the secondary level in computer-assisted geography classrooms (Teh & Fraser, 1994, 1995a, 1995b), chemistry laboratory classes (Wong & Fraser, 1994, 1996), and mathematics and geography classes (Fraser & Chionh, 2000). A study of secondary science classes was also carried out in Taiwan using a Chinese version of the What Is Happening in this Class (WIHIC) questionnaire (Aldridge, Fraser & Huang, 1999). These studies reflect the importance attached to the study of classroom environments and their impact on student learning.

Although a recent study by Fraser (1998a) shows that the majority of classroom environment studies involved Western countries, a number of important studies have been carried out in non-Western countries. Early studies established the validity of classroom instruments that have been translated the Indian (Walberg, Singh, &

Rasher, 1977) and Indonesian (Schibeci, Rideng & Fraser, 1987) languages and replicated associations between student outcomes and classroom environment perceptions. In Hong Kong, qualitative methods involving open-ended questions were used to explore students' perceptions of the learning environment in grade nine classrooms (Wong, 1996). Also, in 1993, Cheung used multilevel analysis to determine the effects of the learning environment on students' learning. The findings of this study provide insights that could help to explain why Hong Kong was found to rank highly in physics, chemistry, and biology in international comparisons (Keeves, 1992).

Recently, studies of associations between student outcomes and classroom environment dimensions have been extended from conventional classrooms into the learning environment of science laboratories. This is best illustrated in the study by Fraser, Giddings and McRobbie (1992a) involving 5447 senior high school and university students in 269 laboratory classes in Australia, the USA, England, Canada, Israel and Nigeria. This cross-national research was the first of its kind in that a new instrument, called the Science Laboratory Environment Inventory (SLEI) and designed for use in laboratory settings, was validated and used in six countries simultaneously. The finding of significant association between the nature science laboratory environment and affective outcomes replicated prior research in science classrooms. The study also contributed to the development and validation of a new Personal form of the SLEI (involving a student's perceptions of his/her own role within the class) to parallel its Class form (involving a student's perception of the class as a whole).

2.8 Other Research on Classroom Environment

This section highlights other lines of learning environment research to complement Section 2.7 which focused specifically on research into associations between student outcomes and classroom environment. A comprehensive picture of the range of past classroom studies can be found in Fraser (1994, 1998a). It discusses nine common lines of research in the field of learning environment: evaluation of curricula and educational innovations; congruence between actual and preferred perceptions; determinants of classroom environments; using perceptions to improve the learning environment; the development of new questionnaires; identifying typologies of learning environments; combining qualitative and quantitative research methods; and school-level environment; and learning environment in school psychology. Each of these lines of research is considered briefly below, whereas Section 2.9 focuses specifically on learning environment studies undertaken in Asia.

2.8.1 Evaluation of Curricula and Educational Innovations

Some studies have incorporated environment dimensions as dependent variables and used instruments such as the Learning Environment Inventory (LEI) and the Individualized Classroom Environment Questionnaire (ICEQ) in evaluating curricula. For example, in studies involving an evaluation of Australian Science Education Project (Fraser, 1979) and Harvard Project Physics (Welch & Walberg, 1972), it was found that classroom environment variables differentiated between curricula, even though there were little differences in student outcomes. Similarly, a study by Teh and Fraser (1993) used classroom dimensions as criterion variables in assessing the efficacy of a computer-assisted learning innovation in secondary geography classrooms. Findings from curriculum evaluations are useful to schools administrators but, as pointed out by (Fraser, 1993), this is a promising but sometimes neglected line of classroom environment research.

2.8.2 Congruence between Actual and Preferred Perceptions

Studies have investigated differences in perceptions between students and teachers in actual and preferred classroom learning environments. This kind of research was made possible by the availability of actual and preferred forms of questionnaires, such as the My Class Inventory (MCI), Individualized Classroom Environment Questionnaire (ICEQ), and Science Laboratory Environment Inventory (SLEI). The separate actual and preferred classroom forms can be used either with students or teachers. Investigations have focused on differences between students and teachers in their perceptions of the same actual classroom environment and that preferred by students or teachers. For example, Fisher and Fraser (1983a) reported a study into differences in perceptions between teachers' and students' perceptions of their actual and preferred classroom environments using the ICEQ. The results indicated that teachers perceived a more positive classroom environment than did their students in the same classroom. These findings replicate emergent patterns in studies carried out in classrooms of secondary schools in the USA (Moos, 1979a), Australia (Raviv, & Reisel, 1990), The Netherlands (Wubbels, Brekelmans & Hooymeyers, 1991), and Singapore (Teh & Fraser, 1993; Wong & Fraser, 1994). These studies emphasize that students and teachers are likely to perceive the nature of the same classroom differently and that students tend to evaluate their actual classroom environment less positively than their preferred environment. Generally, these studies emphasized that students and teachers are likely to perceive the nature of the same classroom differently and that students tend to evaluate their actual classroom environment as less positively and their preferred environment.

The availability of actual and preferred forms of classroom learning environment instruments also facilitates person-environment fit studies. In this line of classroom environment research, a person-environment interactional framework was used to explore whether students achieve better in their preferred environment (Fraser, 1991). Findings from a study in science classes by Fraser and Fisher (1983a, 1983b) suggest that an actual-preferred match in the classroom environment could enhance student outcomes.

2.8.3 Determinants of Classroom Environments

Studies of determinants of classroom environment have been conducted in countries such as the USA, Australia, and Singapore. These studies focused on how the classroom environment varies with factors such as grade level, class size, teacher/student personality, subject content, the nature of school environment (as opposed to classroom environment) and the type of school (e.g., primary compared with junior high schools). Walberg and Anderson (1968a, 1968b) examined classroom climate and student personalities. Walberg (1969) also reported an interesting study of class size differences in learning environment. A study by Owens and Straton (1980) into student preferences for individual types of classroom environment (cooperative, competitive and individualized) revealed that girls preferred a cooperative classroom atmosphere more than boys, whereas boys preferred both competition and individualization more than girls. Gender-related differences in perceptions of classroom environment were examined by Teh and Fraser (1993) in a study of computer-assisted learning environment, by Wong and Fraser (1994) in a study of chemistry laboratory learning environments, and by Margianti and Fraser (2000) in a study of mathematics learning environments in Indonesian university.

2.8.4 Using Student Perceptions in Improving the Learning Environment

Feedback information derived from perceptions of students has been used in another line of classroom environment research in providing meaningful information to guide teachers in their attempts to improve classrooms for learning and teaching. Attempts to improve classroom environment are reported by Fraser and Fisher (1986), Fraser, Malone and Neale (1989), Thorp, Burden and Fraser (1994) and Fraser and Wubbels (1995). A small-scale study of classroom environment by teacher in a secondary school in Singapore, Quek (1993) used a modified version of the Classroom Environment Scale (CES) in its actual and preferred forms. Feedback information obtained from learning environment questionnaires was used as a means of reflection on and improvement in the classroom environment by Yarrow, Millwater, and Fraser (1997) and Sinclair and Fraser (2002).

2.8.5 Development of New Questionnaires

Apart from studies in conventional classrooms and science laboratory settings, there also have been studies conducted in a more technologically-rich classroom environments involving computer-assisted learning. Studies by Maor and Fraser (1996) and Teh and Fraser (1993 1994, 1995a) were undertaken in computer-assisted classroom learning environments. Teh's study in Singapore contributed to the development and validation of a new classroom environment instrument, termed the Geography Classroom Environment Inventory (GCEI). Raaflaub and Fraser (2002) studied laptop computer classrooms and Aldridge, Fraser, Fisher, Trinidad and Wood (2003) studied technology-rich learning environments in a new school in Western Australia. Fisher and Waldrip (1997) reported an instrument for assessing culturally-sensitive factors in science classrooms.

2.8.6 Identifying Typologies of Learning Environments

Research aimed at identifying typologies of classroom environments at universities and high schools represents another area of classroom environment research. The development and validation of the Science Laboratory Environment Inventory (SLEI) (Fraser, Giddings & McRobbie, 1992) for use in laboratory settings made possible further investigations into the state of learning in science laboratories. McRobbie and Fraser (1993b) emphasized the need to develop a systematic typology of science laboratory classrooms, similar to a typology of American high school classroom settings developed by Moos (1978) using the Classroom Environment Scale (CES) and a typology of Dutch physics classes developed by Wubbels, Brekelmans, and Hooymeyers (1991) using the Questionnaire on Teacher Interaction (QTI). Moos labelled the American classes as control oriented, innovation oriented, affiliation oriented, task oriented and competition oriented. On the other hand, Dutch physics classes were described as directive, authoritative, tolerant and authoritative, tolerant, uncertain and tolerant, uncertain and aggressive, aggressive and drudging. The study by McRobbie and Fraser (1993b) identified eight major homogeneous groups in university and high school science laboratory classrooms using the SLEI. This is a promising start to the study of typologies of classrooms.

2.8.7 Combining Qualitative and Quantitative Research Methods

A review of literature on classroom environment research (Fraser, 1998a) indicates the desirability of combining qualitative and quantitative research methods within the same study (Aldridge, Fraser & Huang, 1999; Fraser & Tobin, 1991; Tobin & Fraser, 1998; Tobin, Kahle & Fraser, 1990). Much has been said of the merits of this combination of research methods, with a study by Fraser and Tobin (1989) attesting to the fruitfulness of such an approach.

Significant progress has been made in using qualitative methods in learning environment research and in combining qualitative methods within the same study of classroom environments (Fraser & Tobin, 1991; Tobin & Fraser, 1998). For example, Fraser's (1999) multilevel study of the learning environment incorporated a teacher-researcher perspective of six university-based researchers. The research commenced with an interpretive study of a grade 10 teacher's classroom at a school which provided a challenging learning environment in that many students were from working backgrounds, some were experiencing problems at home, and others had English as a second language. Qualitative methods involved several of the researchers visiting this class each time it met over five weeks, using student diaries, and interviewing the teacher-researcher, students, school administrators and parents. A video camera recorded activities for later analysis. Field notes were written during and after each observation, and team meetings took place three times per week. The main qualitative component of the study was complemented by a minor quantitative component involving the use of classroom environment questionnaires.

The use of quantitative methods has dominated Asian research involving learning environments. There are, however, some notable exceptions in which qualitative methods have been used to advantage. Quite a few Asian studies have used qualitative methods in a minor way, such as in interviews of a small group of students aimed at checking the suitability of a learning environment questionnaire and modifying it before using it in a large-scale study (e.g., Khine, 2001; Margianti et al., 2001a, 2001b; Soerjaningsih et al., 2001a, 2001b). For example, in Singapore, Khoo and Fraser (1998) randomly selected 46 students for interviews in order to cross- check students' questionnaire responses and to obtain richer insights into students' perceptions of their classroom environments. Similarly, in Brunei, Khine and Fisher (2001, 2002) conducted a pilot study in which students were interviewed concerning difficulties experienced in responding to classroom environment surveys.

Wilks' (2000) study of English classes at the senior high school level in Singapore use interpretive and narrative methods to support the validity of a modified version of the Constructivist Learning Environment Survey (CLES). Also these qualitative methods, in conjunction with the questionnaire survey, were used to investigate the extent to which the teaching and learning environment in English classes is consistent with critical constructivism.

Lee's study in Korea involved a strong quantitative component involving the administration of the SLEI, CLES, and QTI to 439 students in 13 classes (four classes from the humanities stream, four classes from the science-orientated stream, and five classes from the science-independent stream) (Lee & Fraser, 2001a, 2001b, 2003). However, also, two or three students from each class were chosen for face to face interviews in the humanities stream and the science-orientated stream. In the case of students in the science-orientated stream, interviews were conducted via the e-mail to overcome practical constraints. All of the face-to-face interviews were audio-taped and later transcribed in Korean and translated into English. When the Korean transcriptions were completed, they were shown to the students to obtain comments and feedback from them, in order to make sure their voices were clearly understood. While the researcher was observing, she wrote down any salient events occurring in the classroom whenever possible. Some photographs were also taken. Field notes were made and translated into English in order to transfer the images into English.

Overall, the findings from interviews and observations replicated the findings from the learning environment surveys. The information from interviews with students mainly contributed to clarifying their replies to questionnaires, but the interviews with the teachers also contributed to drawing conclusions by providing background information about the practical situation in classrooms and schools.

Lastly, in Hong Kong, qualitative methods involving open-ended questions were used to explore students' perceptions of the learning environment in Grade 9 classrooms (Wong, 1993, 1996). This study found that many students identified the teacher as the most crucial element in a positive classroom learning environment. These teachers were found to keep order and discipline whilst creating an atmosphere that was not to boring or solemn. They interacted with the students in ways that could be considered friendly and they showed concern for the students.

As in the case of Western research, the most common line of learning environment research in Asia has involved investigating associations between students' outcomes and their classroom perceptions. These impressive series of studies have taken place in Brunei, Korea, Singapore, and Indonesia in a variety of subject areas (Fraser, 2002). Whereas the use of questionnaires in Asian learning environment research has been prolific, studies which include qualitative methods such as interviews and observations has been less common. Although Asian studies have begun to demonstrate the benefits of combining qualitative and quantitative methods in learning environment research (Lee & Fraser, 2002; Wilks, 2000), it is desirable for learning environment research in Asia to make greater use of qualitative methods.

2.8.8 School-Level Environment

Another desirable trend that has emerged is the development and use of instruments for assessing school environment, such as the School-Level Environment Questionnaire (SLEQ) (Burden & Fraser, 1994; Fisher & Fraser, 1991). Findings from a study (Fisher & Fraser, 1991) using the SLEQ yielded interesting differences between the school climates of primary and secondary schools (Fraser, 1993b). A distinction has been made between research into school climate or environment (e.g., Fraser & Rentoul, 1982) and research into classroom climate or environment. However, it is envisaged that the integration of classroom and school environment variables within the same study will provide scope for teachers to gather information regarding the environment (both class and school) in which they work. In turn, this information is likely to equip the teachers with a sound basis for improving the quality of their working environment and professional lives (Dorman, 2000a, 2000b; Fraser, 1993b).

Docker, Fraser and Fisher (1989) reported the use of the WES with a sample of 599 teachers in investigating differences between the environment of various school types. Reasonably similarity was found for preferred environment scales, but teachers' perceptions of their actual school environments varied markedly in that the climate in primary school was more favorable than the environment of high schools on most scales. For example primary school was viewed as having greater Involvement, Staff Support, Autonomy, Task Orientation, Clarity, Innovation and Physical Comfort and less Work Pressure. Similarly, when the SLEQ was used in a study of differences between the climates of primary and high schools for a sample of 109 teachers in 10 schools (Fisher & Fraser, 1991), the most striking finding was that the climate in primary schools emerged as more favorable than the environment of high schools on most SLEQ scales.

Dorman and Fraser (1996) used a school environment questionnaire based on the SLEQ in a comparison of Catholic and government schools. Data from 208 science and religion teachers from 32 schools showed significant differences of approximately one standard deviation between two school types on teacher-perceived Mission Consensus and Empowerment. Catholic teachers saw their school as more empowering and higher on Mission Consensus than government school teachers.

2.8.9 Learning Environment in School Psychology

Given the school psychologist's changing role, the field of psychosocial learning environment provides a good example of an area which furnishes a number of ideas, techniques and research findings which could be valuable in school psychology (Fraser, 1987; Hertz-Lazarowitz & Od-Cohen, 1992). Traditionally, school psychologists have tended to concentrate heavily and sometimes exclusively on their roles in assessing and enhancing academic achievement and other valued learning outcomes. The field of classroom environment provides an opportunity for school psychologists and teachers to become sensitized to subtle but important aspects of school life, and to use discrepancies between students' perceptions of actual and preferred environment as a basis to guide improvements in classrooms (Burden & Fraser, 1993). Similarly, expertise in assessing and improving school environment can be considered valuable in the work of educational psychologists (Burden & Fraser 1994).

2.9 Studies Carried Out in Asia

Although learning environment research originated in Western countries, Asian researchers in the last decade have made many major and distinctive contributions. Some of the main questionnaires that were developed in the West have been adapted (sometimes involving translation into another language) and cross-validated for use in several Asian countries. Another desirable trend has emerged with the development and use of instruments for assessing learning environment in Asian countries (Goh & Khine, 2002). Research also includes studies in Singapore (Chionh & Fraser, 1998; Fraser & Chionh, 2000; Goh & Fraser, 1998; Goh, Young, & Fraser, 1995; Teh & Fraser, 1993, 1994, 1995a, 1995b; Wong & Fraser, 1994, 1995, 1996), Brunei (Riah & Fraser, 1998; Scott & Fisher, 2000), Korea (Kim, Fisher & Fraser, 1999; Lee & Fraser, 2001, 2003), Taiwan (Aldridge & Fraser, 2000; Aldridge, Fraser & Huang, 1999; Aldridge, Fraser, Taylor & Chen, 2000), and Indonesia (Fraser, 1985; Fraser, Pearse & Azmi, 1982; Margianti & Fraser, 2000; Paige, 1978, 1979; Schibeci, Rideng & Fraser, 1987). These studies include some examples of research that successfully translated questionnaires into the national language. For example, past Asian research studies established the validity of classroom environment instruments that had been translated into the Indian (Walberg, Singh, & Rasher, 1997) and Indonesian (Schibeci, Rideng & Fraser, 1987) languages and replicated associations between student outcomes and classroom environment perceptions.

Finally, there is scope for Asian researchers to adopt, adapt or create new theoretical frames to guide the next generation of learning environment studies. For example, this could build upon Roth's (1999), advice against conceptualizing the environment as being independent of the person, and on his use of life-world analysis as a new theoretical underpinning. Roth, Tobin and Zimmerman (2002) break with past traditions by taking researchers into the front lines of the daily work of schools, thereby assisting in bringing about change. They propose co-teaching as an equitable inquiry into teaching and learning processes in which all members of a classroom community participate – including students, teachers, student teachers, researchers and supervisors. Roth and colleagues articulate co-teaching in terms of activity theory and the associated first-person methodology for doing research on learning environments that is relevant to practice.

2.10 Summary

This chapter provides a definition of environment as the shared perceptions of students and sometimes teachers in the classroom (Fraser, 1986), and distinguishes two types of classroom environment: the human and physical environment. It provides a historical account of the theoretical perspectives that underpin classroom environment research and interpersonal teacher behaviour, and a review of research into associations between students' achievement, attitudes, and learning environment.

Two perspectives were offered in terms of the human environment: the first includes the students and teachers in a classroom and their interaction with each other; and, in the second, the human environment encompasses how the teacher facilitates learning and plays an important role in making it more conducive to learning for the students. The physical environment, on the other hand, includes the material and setting, including the furniture, lighting and how the objects and furniture are laid out in the classroom.

The background history suggests that the field of learning environment research began with the work of Lewin and Murray in the 1930s, followed by others such as Moos, Walberg and Fraser. These researchers laid theoretical foundations for classroom environment research. The pioneering work of Moos and Walberg, and the elaborations by Fraser and his colleagues, has made classroom environment work a distinct field of research for the last 40 years. A look at the field of learning environment over the past few decades shows that an important feature is that of the availability of a variety of valid, economical and widely-applicable questionnaires that have been developed and used for measuring students' perceptions of classroom environment. Fraser (1993a) points out five main considerations for justifying the use of perceptual measures. First the use of questionnaires to capture perceptions of students and teachers is more economical than the process of having trained observers making the observations. Second, data from such measures are based on perceptions of students over a period of time, while classroom observations are limited usually to a small number of lessons. Third, perceptual measures bring together the pooled opinions of all students in a class, whereas classroom observation generally involves the perceptions of only one observer. Fourth, student perceptions account for considerable more variance in student learning outcomes than do directly-observed variables in classrooms. Fifth, student perceptions are the determinants of student behaviour more so than real situation, and so can be more important than observed behaviour.

This review indicates that the classroom environment research opens new windows for viewing the teaching and learning process. The number of validated classroom environment questionnaires available makes it possible for educators to investigate the nature of the learning environment in classrooms and laboratory classroom settings from teachers' and students' perspectives. Each of the instruments is a paper-and-pencil questionnaire tapping the perceptions of students and teachers of different psychosocial dimensions of their classroom.

A review of literature reveals that the strongest research tradition in past classroom environment research has been in the investigation of associations between student outcomes and student perceptions of psychosocial characteristics of their classroom environments (Fraser, 1989, 1994, 1998a, 1998c; Fraser & Walberg, 1991; Haertel, Walberg, & Haertel, 1981). Research using perceptions of both teachers and students across varying grade levels (elementary, middle, high and higher education), different subject areas (science, mathematics, languages) different types of schools and various countries (USA, Canada, Australia, Israel, and Asia) tends to support the contention that the learning environments of classrooms account for considerable variance in student outcomes.

Past studies involving various other lines of learning environment research were reviewed, including emerging traditions of learning environment research in Asian countries. Of particular relevance to my study, studies in which learning environment dimensions were utilized as dependent variables in the evaluation of educational innovations were considered.

CHAPTER 3

RESEARCH METHODS

3.1 Introduction

The present study involved students in Grades 4 and 5 in elementary schools in the diverse Miami-Dade County Public Schools (MDCPS) district. The aim of my research was to evaluate the effectiveness of using manipulatives in mathematics in terms of achievement, attitudes and the learning environment. To assess student achievement, an achievement test was developed patterned after the Florida Comprehensive Assessment Test (FCAT) and administered to students in the state of Florida by the Department of Education (DOE). An attitude questionnaire based on the Test Of Science-Related Attitudes (TOSRA) was used to assess students' attitudes toward mathematics. Finally, several existing learning environment instruments were modified and used to assess the classroom environment as perceived by the students.

Influenced by the unimpressive performance of students on the Florida Comprehensive Assessment Test (FCAT) (in the state of Florida overall and the Miami-Dade County Public Schools district in particular) and on international comparisons of achievement in the TIMSS (1997) and TIMSS-R (1999) reports, school districts in the state decided to change the methods of instruction in an effort to raise test scores in 1998. The Miami-Dade County Public Schools' (MDCPS) curriculum planners moved away from the traditional methods of evaluation, dominated by multiple-choice tests, to methods including critical thinking and explanation of answers using expanded-response or short-response formats. Whereas students previously used traditional methods of choosing multiple-choice answers to questions on standardized tests, they now are required to use critical thinking strategies and to write explanations for answers. This created a problem because teachers were accustomed to students memorizing and using pattern recognition rather than exhibiting understanding (Buxton, 1978).

The overall purpose of the study was to determine whether the use of hands-on manipulatives in mathematics enhanced achievement, attitudes and classroom environment among selected fourth and fifth graders in a Miami-Dade County elementary school in Florida, USA. This research project also investigated whether the classroom environment is related to students' attitudes toward mathematics and achievement test scores.

The study was divided into two phases. Phase 1 was conducted with 422 Grades 4 and 5 students in a Miami-Dade County Public Schools (MDCPS) elementary school located in a predominantly Hispanic neighborhood. The key factor of the design of Phase 1 was that two instructional groups using manipulatives to different degrees were compared. The criteria of evaluation involved an achievement test, modified versions of three learning environment instruments (the My Class Inventory, MCI; the Science Laboratory Environment Inventory, SLEI; and the Questionnaire on Teacher Interaction, QTI) and an attitude scale (Appendix F) based on the Test of Science-Related Attitude (TOSRA).

Phase 2 of my study was conducted in four elementary schools in the diverse Miami-Dade County Public Schools (MDCPS) district. Distinctive features of the design of Phase 2 are that changes over time were monitored using a pre-post design and that an improved measure of classroom environment was used. The learning environment instrument used was the What Is Happening In this Class? (WIHIC). Also I measured student attitudes based on the Test Of Science-Related Attitudes (TOSRA). Altogether, in Phase 2, 375 participants completed the instruments online using computers in the school's computer lababoratory and submitted their responses electronically to a database, SurveyGold.

This chapter describes and justifies the two phases of the present study in terms of: the research design (Section 3.2); the sample (Section 3.3); the instructional approaches (3.4); the instruments used (Section 3.5); the methods for analysing the data (Section 3.6); the balance of qualitative and quantitative approaches used in my study (3.7); and a summary (Section 3.8).

3.2 Research Design

My study was undertaken in two phases because the planned sample size for the first phase was limited for various reasons. For example, the first phase of the study was narrow because it involved just one school. Phase 2 sought to correct this by involving a further 375 fourth and fifth graders in four elementary schools in the diverse Miami-Dade County Public Schools (MDCPS) district. Another important reason for including Phase 2 had to do with limitations with the questionnaires used in Phase 1. One of the central problems with the questionnaires in Phase 1 was that the learning environment and attitude scales had too few items to enable the researcher to establish strong levels of reliability and validity. Another was that some students had problems reading the questions because of their limited reading ability. Also, in Phase 1, the Test Of Mathematics-Related Attitude (TOMRA) used responses ranging from Strongly Agree to Strongly Disagree which probably confused students because they were different response alternatives from the frequency scale used with the learning environment scales (Almost Never to Almost Always).

Phase 2 involved an online survey which instructed students to give their opinions about their mathematics class using frequency responses ranging from Almost Never to Almost Always for the same two scales of the TOMRA. The response choices were changed for Phase 2 because the scales were modified and combined with the WIHIC learning environment questionnaire as an online survey. For Phase 2 of my study, two scales from the modified TOMRA and five scales from What Is Happening In this Class? (WIHIC) were used. In Phase 2 of the study, more items per scale were used than in Phase 1 to ensure better validity and reliability. Although the questionnaires were modified, students whose native language was not English still had difficulty reading and understanding the questions, and this resulted in many items not being answered correctly. Also, some students worked slowly and required more time to read and respond to the questionnaires.

Instead of having two different groups which used manipulatives for differing amounts of time as in Phase 1, Phase 2 involved a pre-post design in which changes in WIHIC and the TOMRA scores were investigated during a period when students used manipulatives during mathematics instruction.

3.2.1 Design of Phase 1

Phase 1 of the study used a quasi-experimental research design. In Phase 1 of this study, the experimental group comprised all students of teachers (determined by a Teacher Survey previously administered) see (Appendix H) who used manipulatives for an average of at least 60% of the time during all mathematical strand activities in their class/section. The teachers were required to complete a survey prior to administering an achievement test to determine which students would be part of the comparison group in both grades. This was determined whenever a strand was taught and the teacher used the manipulatives provided for that activity. Because the experimental group used manipulatives to solve 15 or more questions on the achievement test, then at least 60% of all the mathematical strands activities were covered in that class/section.

The comparison group for Phase 1 comprised students whose teachers reported on the Teacher Survey that they had decided to use hands-on manipulatives for an average of less than 40% of the time on all mathematical strand activities in their class/section. This was determined by those teachers allowing their students to use hands-on activities for 10 or less questions on the achievement test for all mathematical strands in that class/section. The school's administrators suggested that the grouping be on a percentage usage basis to allow all students to use some sort of manipulatives while doing mathematics activities. The achievement test, provided as

Appendices A and B for Grades 4 and, 5 respectively, was used only in Phase 1 of my study.

The groups were taught using strategies designed by the Florida Department of Education (DOE) and the Miami-Dade County Public Schools (MDCPS) district. Students were requested to explain answers using an extended-response or the short-response to questions. Students also were trained to bubble in the correct answer for each response for multiple-choice questions. For some multiple-choice questions, students practiced bubbling answers on grids (gridded response). However, for this study, only multiple-choice questions were used for both Grades 4 and 5 as scoring performance-based items would create a problem. When creating the questions and writing rubrics for these items, the interpretation of these items by each teacher could be different; therefore, students just answered multiple-choice questions. Overall, students were also taught using strategies outlined in the State of Florida's Sunshine State Standards Item Specifications which gave examples of types of items designed for the state's achievement test. The teachers were required to complete a survey prior to administering the achievement test to determine which students would be part of the comparison group in both grades for this phase of the study.

An important weakness of Phase 1 of this study was that the experimental and control groups were reasonably similar with respect to the level of usage of manipulatives. Another potential shortcoming was the inability of some students to read the items in the achievement test and the questionnaires. An additional weakness was time management; many students were unable to answer all the questions in the allotted time because of the readability of the instruments for students whose native language was not English. In future studies, students might need extra time to practice for tests of this nature.

3.2.2 Design for Phase 2

As mentioned above, Phase 2 of the study was intended to overcome some weaknesses in the design of Phase 1. First, whereas the sample in Phase 1 was drawn from a single school, the sample for Phase 2 of this study consisted of 375 participants from 20 fourth and fifth grade classes from four diverse schools in the Miami-Dade County Public Schools (MDCPS) district. There were 11 fourth grades and 9 fifth grades in four elementary schools with a very diverse population that encompasses students from various South American and Caribbean countries, as well as those born in the United States.

Second, because of problems encountered with the validity and reliability of learning environment surveys used in Phase 1 of the study (namely, MCI, SLEI, and QTI), I used five scales from the What Is Happening In this Class? (WIHIC) in an online survey for Phase 2. The WIHIC was developed to bring parsimony to the field of learning environment by drawing on the most relevant scales from older instruments and adding dimensions of contemporary relevance. The WIHIC has exhibited strong factorial validity and internal consistency when used in Australia (Fraser, Fisher, & McRobbie, 1996), Canada (Zandvliet & Fraser, 1999, 2004, 2005) Singapore (Choinh & Fraser, 1998), and Taiwan (Aldridge & Fraser, 2000). A two-scale modified version of the TOSRA was used in Phase 2, but there was no achievement measure used in Phase 2.

The online questionnaires for Phase 2 of my study were first administered as a pretest at the beginning of the second grading period for the Miami-Dade County Public Schools (MDCPS) district. (A grading period is nine weeks of school.) Both the WIHIC and the TOMRA (Appendix G) questionnaires were administered as a posttest not in the ninth week of the second grading period as was proposed, but two weeks later as the school district was administering one of its Quarterly Assessment tests.

The researcher met with the school site administrators, teachers in the fourth and fifth grades, and the schools' Technology Facilitator to give detailed directions for administering the questionnaires during the students' scheduled computer laboratory time. For both the pretest and posttest, students were brought to the school's computer laboratory where the Technology Facilitator gave directions and observed as each student completed the questionnaires online. When each item was completed, the students submitted all of their response to the SurveyGold database. The researcher was notified instantly by email that the students had completed the survey.

In Phase 2 of the study, however, because the What Is Happening In this Class? (WIHIC) and the Test of Related-Mathematics Attitude (TOMRA) questionnaires were administered as online instruments, the students were prompted to complete all questions before it could be submitted to the database and, therefore, mistakes were minimal. Although the readability of the questionnaire was a factor for these participants in Phase 2 of this study as well, they spent more time answering each item as they could not submit to the database before they responded to each question. Time was not restricted as the participants had to complete all the questions in the instrument before they were allowed to submit responses to the SurveyGold database.

3.3 Sample

3.3.1 Sample for Phase 1

Phase 1 of my study was conducted during the first nine-week grading period of the 2001–2002 school year of the Miami-Dade County Public Schools (MDCPS) district. The participants were from one predominantly Hispanic elementary school in the Miami-Dade County Public Schools (MDCPS) district. Students in Grades 4 and 5 participated in the study. The students were randomly selected by the school's counselors to form sections. The two grades were divided into sections 401 through 409 and 501 through 509. Although a total of 612 students in 18 classes were selected to respond to the questionnaires, only 442 students had usable and complete data. These 442 students accounted for about 72% of the total number of students in the fourth and fifth grades. The sample provided a fair representation of the students in the fourth and fifth grades at this predominantly Hispanic elementary school in the Miami-Dade County Public Schools district. The rest of the responses (of the 612) contained errors from students who did not follow directions correctly, for whom the reading level of the test and questionnaires were too difficult, and for whom the first language was not English. The fact that most of the participants spoke or read English as a second language might have been a factor as well in the low response to the items on the achievement test and questionnaires.

3.3.2 Sample for Phase 2

In Phase 2 of my study, 375 students in 20 classes from four diverse elementary schools, typical of the school district's Hispanic, Haitian American, African American, and Anglo population, were the participants. The sample for this part of the study mirrors the general population of students in these particular schools. The reading levels of the participants were similar to students in Phase 1 of the study, with their parents being from countries other than the United States and having English is a second language. The advantage of using these schools is that they are located in a very diverse area where the population, although mixed, is representative.

3.4 Instructional Approaches

3.4.1 Instructional Approaches in Phase 1

The experimental group in Phase 1 of my study used hands-on manipulatives for at least 60% of the instructional time for each mathematical strand. The nine teachers who taught the experimental group in Phase 1 used a variety of teaching styles. Instead of depending primarily on lectures to introduce the content, students were encouraged to play with manipulatives first for 5–10 minutes in order to become actively engaged in discussion, to pair-share activities, to make journal entries, or to jot down what they had learned in learning logs at the end of class. The teachers also encouraged the students to use problem-solving strategies – look for a pattern, use logic, make an organized list and act out the problem. Extended projects, for which students were asked to create various representations using the manipulatives, were constantly recommended for the experimental group. The majority of the lessons began with either a realistic scenario or students exploring mathematical ideas. For example, students purchased materials from a make-believe store in the classroom using play money, or they discussed the question “What if there were no money in the world?”

In contrast, the comparison group in Phase 1 of the study used hands-on manipulatives for 40% or less of the mathematical strands, with the teachers using a variety of traditional strategies to help them to understand and solve problems. Teachers posed problems, encouraged discussion, and engaged students in activities that involved reflection on their learning. Those teachers followed a more knowledge-based mathematical approach as they encouraged students to reflect on what and how they taught. The comparison group also allowed students to pair-share and to practice exercises from a given text or practice book. The participants were also encouraged to make connections to real-life situations based on the given problems. Activities in which the participants generated graphs were followed up by questions, which asked them to observe patterns and to form conjectures or make connections to their daily lives. Although verbal interactions were lively and frequent, the participants seemed restricted because they did not use manipulatives as frequently as the experimental group.

As noted previously, a limitation to my study for Phase 1 was that both groups used manipulatives but for different amounts of time and that, therefore, there is potential for confounding in the interpretation of the findings.

3.4.2 Instructional Approaches in Phase 2

In the second phase of my study, the 20 teachers (11 fourth grade and 9 fifth grades) agreed to administer a pretest at the beginning of the grading period (nine weeks of school in Miami-Dade County Public Schools is considered a grading period) and a posttest at the end of the second grading period. The purpose of these was to see if there would be pre-post changes during the time when students used manipulatives in their mathematics instruction. My second research question involved evaluating the use of hands-on manipulatives in terms of changes in student attitudes and the classroom environment (but achievement was not involved in Phase 2 of the study).

For Phase 2 of the study, some teachers placed manipulative kits on the students' desks and instructed them to use them whenever they wanted to. Other teachers, however, just allowed students to use manipulatives whenever the strand of mathematics required it (i.e. only if the students' textbook suggested the use of manipulatives to answer specific problem). The students, whose manipulative kits were kept on their desks, used them all the time to help them to solve various types of mathematics problems.

A potential weakness in the design of Phase 2 could be that some teachers used manipulatives less than intended. Although it is a policy within the Miami-Dade County Public Schools (MDCPS) district for teachers to use manipulatives wherever possible in all five mathematics strands, not all teachers adhere to this policy. This might be because some teachers need inservice courses in the use of manipulatives or because they were set in their traditional approaches to mathematics instructions.

Some teachers, perhaps in an effort to teach to the Florida Comprehensive Assessment Test (FCAT), failed to devote the time necessary to use hands-on manipulatives effectively.

Another potential problem in the design of Phase 2 could be that some students were previously using manipulatives prior to my study, and therefore that some of the benefits of using manipulatives might already have been realized at the time of my pretesting.

3.5 Instruments

Chapter 2 reviewed past studies that have reported the successful use of classroom environment instruments that originated in many countries and in a variety of cultural settings, including Asian countries (Aldridge, Fraser, & Huang 1999; Chionh & Fraser, 1998; Goh & Fraser, 1995; Goh, Young & Fraser, 1995; Khoo & Fraser, 1997; Teh & Fraser, 1993; Walberg, Singh & Rasher, 1997; Wong & Fraser, 1994, 1996). These studies gave me confidence to use classroom learning environment instruments in my study.

One important decision for Phase 1 of my study was the choice of questionnaires to assess the nature of the classroom learning environment. The rationale for my choice of learning environment instruments is given in Sections 3.5.1 to 3.5.3. Two classroom environment instruments chosen were the My Class Inventory (MCI; Fraser & O'Brien, 1985) and the Science Laboratory Environment Inventory (SLEI; Fraser, Giddings & McRobbie, 1992a, 1992b, 1995; Fraser & McRobbie, 1995;

Fraser, McRobbie & Giddings, 1993). To assess the quality of teacher-student relationships in the classroom environment, the Questionnaire on Teacher Interaction (QTI; Goh & Fraser, 1998) was utilized. For Phase 2 of my study, however, the WIHIC was used to assess the students' learning environment.

Items from the Test Of Mathematics-Related Attitudes (TOMRA) was used to assess students' attitude towards mathematics in both phases of my study. Various achievement tests were used in Phase 1, but achievement was not assessed in Phase 2. The section below details how the instruments were modified for use with students from a diverse population.

3.5.1 Modification to Instruments

Before the instruments could be used in Phase 1 of this study, it was important to ensure that they were suitable for use with elementary school students in a diverse school community. The adaptation process involved a number of steps. The scales from the different instruments were selected according to their suitability for use with elementary school students in a diverse Hispanic community in the Miami-Dade County Public Schools district, Florida, United States. The wording of some items was changed to make them more suitable. For example, 'pupil' was changed to 'student', which is a more familiar word for participants. Because the researcher was aware of time constraints that would be in place, the numbers of items were reduced. Finally, the instructions for administering the instruments were changed and teachers were allowed to read the directions and instruct students to bubble answer choices on a separate answer sheet for Phase 1 of the study. Because of the small number of items per scale in Phase 1 of this study (15 items in 5 scales for the MCI, 12 items in four scales for the QTI, and 15 items in 5 scales for the SLEI), not surprisingly, it was not possible to replicate the *a priori* factor structure for each instrument (see Chapter 4). Only 4 of the 8 QTI's scales were included in my study.

3.5.2 Assessing Classroom Environment in Phase 1

3.5.2.1 My Class Inventory (MCI)

This instrument was used in Phase 1 of my study only. It is a simplified version of the Learning Environment Instrument (LEI) for use among students aged 8–12 years (Fisher & Fraser, 1981; Fraser, Anderson & Walberg, 1982; Fraser & O'Brien 1985). The MCI differs from the LEI in four important ways. First, in order to minimize fatigue among younger participants, the MCI contains only five of the EI's original 15 scales. Second, item wording has been simplified to enhance readability. Third, the LEI's four-point response format has been reduced to a two-point (Yes, No) response format. Fourth, students' answers to the questionnaire are recorded on the same page as the items instead of on a separate response sheet, to avoid errors in transferring responses from one place to another. In Singapore, Goh, Young and Fraser (1995) changed the MCI's original Yes–No response format to a three-point response format (Seldom, Sometimes, and Most of the Time). Also, in Brunei, Darussalam, Majeed, Fraser, and Aldridge (2002) used the original version of the MCI with 1565 mathematics students in 39 classes in 15 government secondary schools. When the Satisfaction scale was used as an attitudinal outcome variable, instead of as a measure of classroom environment, Majeed et al. (1999) found strong support for a three-factor structure for the MCI consisting of three of the four *a priori* scales, namely, Cohesiveness, Difficulty and Competitiveness.

The Student Actual Short Form and the Student Preferred Short Form of the MCI (Appendix C) were utilized it my study. They each had 15 items. The original version had 25 items in 5 scales. Both versions assess Student Cohesiveness, Friction, Satisfaction, Difficulty, and Competitiveness. One characteristic of the Actual Form of MCI is that it has been found to be capable of differentiating between the perceptions of students in different classrooms (Fraser & Fisher, 1983a, 1983b). That is, students within the same classroom perceive things relatively similarly, while mean within-class perceptions vary from classroom to classroom. Teachers in my study were encouraged to administer the questionnaires to individual students and were also instructed to read just the directions and have students write their identification number and class/section on each instrument. Table 3.1 below gives a description and sample item for each scale in the original form of the MCI.

TABLE 3.1 Descriptive Information for Each MCI Scale

Scale Name	Description	Sample Item
Satisfaction	Degree to which students enjoy learning.	The students enjoy their project work in class.
Friction	Degree to which students do not get along and are unfriendly to one another.	Certain students want to have their own way.
Competitiveness	Degree to which students compete with classmates.	Students often race to see who can finish.
Difficulty	Degree to which students experience difficulty in their learning tasks.	In my class the project work is hard to do.
Cohesiveness	Degree to which students feel a sense of belonging.	In my class everybody is my friend.

3.5.2.2 Science Laboratory Environment Inventory (SLEI)

The Science Laboratory Environment Inventory (Appendix D), used only for Phase 1 of the study, is an instrument designed to fulfil another need, namely, that of assessing the environment of science laboratory classes at high school or higher education levels (Fraser, Giddings, & McRobbie, 1992a, 1992b, 1995; Fraser & McRobbie, 1995; Fraser, McRobbie & Giddings, 1993). The original version of the instrument has 35 items in 5 scales (Student Cohesiveness, Open-Endedness, Investigation, Rule Clarity and Material Environment). For the purpose of this study, the SLEI was adapted for use with elementary school students in Grades 4 and 5 in a Miami-Dade County Public Schools (MDCPS), Florida, United States. The questionnaire was reduced to 15 items describing Student Cohesiveness, Open-Endedness, Integration, Rule Clarity, and Material Environment. Table 3.2 gives a description and a sample item for the original version of the SLEI utilized in my study.

The items in the SLEI are arranged in blocks of five. The first item in each block assesses student Cohesiveness, the second item in each block assesses Open-Endedness, the third item in each block assesses Integration, the fourth item in each block assesses Rule Clarity, and the fifth item in each block assesses Material Environment. The teachers in my study were encouraged to read the instructions and to fill in the student's identification number and class/section. Participants then read the questions and circled their selected responses from the alternatives of Almost Never, Seldom, Sometimes, Often, and Very Often. The scales in these instruments were shortened because the students are of Hispanic descent, and most of them were learning English as a second language.

TABLE 3.2 Descriptive Information for Each SLEI Scale

Scale Name	Description	Sample Item
Student Cohesiveness	Extent to which students know, help and are supportive of one another.	I get along with students in this mathematics class. (+)
Open-Endedness	Extent to which the mathematics activities emphasize an open-ended divergent approach to experimentation.	In my mathematics class the teacher decides the best way for me to do the mathematics activities. (-)
Integration	Extent to which the laboratory activities are integrated with non-laboratory and theory classes.	I use the theory from my regular science class session during laboratory activities. (+)
Rule Clarity	Extent to which behavior in the laboratory is guided by formal rules.	There is a recognized way for me to do things safely in the laboratory. (+)
Material Environment	Extent to which the laboratory equipment and materials are adequate.	I find that the laboratory is crowded when I am doing experiments. (-)

(-) Reversed-scored items

3.5.2.3 Questionnaire on Teacher Interaction (QTI)

The original Questionnaire on Teacher Interaction, consisting of 48 items in 8 scales, was selected for Phase 1 of this study only. The eight scales of teacher interaction behavior (Leadership, Understanding, Helping/Friendly, Student Responsibility/Freedom, Uncertain, Dissatisfied, Admonishing and Strict behavior) fall naturally within Moos' (1974) category of relationship dimensions. Each item has a five-point response scale ranging from Never to Always. Research with the QTI has been completed at various grade levels in the United States (Wubbels & Levy, 1993) and Australia (Fisher, Henderson & Fraser, 1995). In Indonesia, Soerjaningsih, Fraser and Aldridge (2001, 2002) translated the QTI into Indonesian language and cross-validated it with a sample of 422 university students in 12 research method classes. A short version for elementary students (Goh & Fraser, 1996) has the same eight scales but differs from the earlier high school version in two main ways. Firstly, some items at a high reading level were modified and reworded into simpler language that is more suitable for younger students. Secondly, the elementary version has a three-point response scale anchored by Seldom, Sometimes, and Most of the Times in comparison with the five-point response scale anchored by Always and Never in the high school version.

The version of the QTI used in my study (described in Table 3.3 below), consists of 12 items focusing on the nature and quality of interpersonal relationships between teachers and students (Appendix E). The scales selected for my study were Leadership, Understanding, Uncertain, and Admonishing behavior. The scales were modified in my study to suit the reading ability of the students and items were shortened to reduce the time for administering the questionnaire. Teachers were instructed to have students write their identification number and class/section identification on the questionnaire and have participants circle the number corresponds to their response (0 through 4).

TABLE 3.3 Descriptive Information for Each QTI Scale

Scale Name	Description	Sample Item
Leadership	Leads, organizes, gives orders, determines procedures and structures the classroom situation.	The teacher talks enthusiastically.
Helping/Friendly	Shows interest, behaves in a friendly or considerate manner and inspires confidence and trust.	The teacher helps us with our work.
Understanding	Listens with interest, empathizes, shows confidence and understanding and is open with students.	The teacher trusts us.
Student Responsibility/ Freedom	Gives opportunity for independent work, gives freedom and responsibility to students.	We can decide some things in this teacher's class.
Uncertain	Behaves in an uncertain manner and keeps a low profile.	The teacher seems uncertain.
Dissatisfied	Expresses dissatisfaction, looks unhappy, criticizes, and waits for silence.	The teacher thinks that we cheat.
Admonishing	Gets angry, expresses irritation and anger, forbids and punishes.	The teacher gets angry unexpectedly.
Strict	Checks, maintains silence and strictly enforces the rules.	The teacher is strict.

3.5.3 Assessing Student Attitudes to Mathematics in Phases 1 and 2

A questionnaire was designed to measure students' attitude towards mathematics. Items in the questionnaire were modified from Fraser's (1981b) Test Of Science-Related Attitude (TOSRA), which was designed to measure students' science attitudes in secondary school. The original TOSRA had 7 scales with a total of 70 items. The Test Of Mathematics-Related Attitude (TOMRA) was adapted to suit the needs of elementary mathematics.

The questionnaire was modified because its original 70 questions were too many for elementary students and because the reading level of the items was above the students' reading ability. Modification was necessary or else the teachers would have to read each item and student interpretations could vary depending on the reader's tone and mannerism. There would also have to be more time allotted for the students to complete the questionnaire. The version of TOMRA used in my study was modified in two main ways. First, the structure, design and format of the TOMRA questions were kept identical to the original version but, wherever the word 'science' appeared, it was replaced with 'mathematics'. Secondly, only a selection of the original items from TOSRA was used. Table 3.4 provides a description and a sample item for each scale in the original version of the TOSRA.

In Phase I of my study, I selected only items for one of TOSRA's original scales (involving enjoyment of lessons). I retained TOSRA's original response alternatives of Strongly Disagree, Disagree, Not Sure, Agree and Strongly Disagree.

In Phase 2, I used an improved two-scale version of TOMRA to assess Adoption of Mathematical Attitudes and Enjoyment of Mathematics Lessons (based on two of TOSRA's original scales). Also, to make it easier for students to answer, I changed the TOSRA's original response format to make it identical to the response format of the WHICH (Almost Never, Seldom, Sometimes, Often and Almost Always).

TABLE 3.4 Descriptive Information for Each TOMRA Scale

Scale Name	Description	Sample Item
Social Implications of Mathematics	Manifestation of a favorable attitude towards mathematics and mathematicians.	Money spent on mathematics is worth spending.
Normality of Mathematicians	Manifestation of a favorable attitude towards mathematics and mathematicians.	When I leave school I would like to work with people who make discoveries in mathematics.
Attitude to Mathematical Inquiry	Acceptance of mathematical inquiry as a way of thought	I would rather solve a problem by doing it myself than to be told the answer.
Adoption of Mathematical Attitudes	Adoption of mathematical attitudes.	A career as a mathematician would be interesting.
Enjoyment of Mathematics Lessons	Enjoyment of mathematics learning experiences.	I really enjoy going to mathematics lessons.
Leisure Interest in Mathematics	Development of interest in mathematics and mathematics-related activities.	I like reading newspaper articles in mathematics.
Career Interest in Mathematics	Development of interest in pursuing a career in mathematics.	Working as a mathematician would be an interesting way to make a living.

3.5.4 Assessing Classroom Environment in Phase 2: What Is Happening In this Class? (WIHIC)

To provide a view of the learning environment of elementary school mathematics classes, the What Is Happening In this Class? (WIHIC) questionnaire was administered to 375 students in four elementary schools in Phase 2 of my study.

Developed by Fraser, McRobbie and Fisher (1996), the WIHIC measures students' perceptions of their classroom environment.

I used a modified version of the What Is Happening In this Class? to provide data regarding students' perceptions of learning environment in my study. The WIHIC's five scales of Student Cohesiveness, Teacher Support, Involvement, Task Orientation and Cooperation were selected in Phase 2 of my study.

A number of instruments have been developed over the past 20 years to measure classroom environments (Fraser, 1991; Fraser, 1994). Each of these instruments has been used in research and has demonstrated reliability in comprehensive field trials. According to Fraser, McRobbie and Fisher (1996), earlier instruments, including the Learning Environment Inventory (LEI; Anderson & Walberg, 1974; Fraser, Anderson & Walberg, 1982) and Classroom Environment Scale (CES; Moos & Trickett, 1974), contain items that are more relevant to teacher-centered classrooms than to the student-centered settings that are more common today.

The WIHIC measures a wide range of dimensions which are relevant to present-day situations in the classrooms. Fraser, McRobbie, and Fisher, (1996), states that it includes important dimensions from past questionnaires and combines them with dimensions that measures aspects of constructivism and other emphases relevant to the environment of contemporary classrooms. A scale description and sample item for each scale in the original form of the WIHIC is included in Table 3.5.

TABLE 3.5 Descriptive Information for Each WIHIC Scale

Scale Name	Description	Sample Item
Student Cohesiveness	Extent to which students know, help and are supportive of each other.	I work well with others.
Teacher Support	Extent to which the teacher helps, befriends, trusts and is interested in students.	The teacher talks with me.
Involvement	Extent to which students have attentive interest, participate in discussions.	I do additional work and enjoy the class.
Investigation	Emphasis on the skills and processes of inquiry and their use in problem solving and investigation.	I am given a choice in which investigations I do.
Task Orientation	Extent to which it is important to complete activities planned and to stay on subject matter.	I know what has to be done in this class.
Cooperation	Extent to which students cooperate rather than compete with one another on learning tasks.	I cooperate with other students when doing assignment work.
Equity	Extent to which students are treated equally by the teacher.	I get to use the equipment as much as other students.

The WIHIC uses a five-point frequency response scale and requires students to signify how often they perceive a classroom practice is occurring. The response alternatives of Almost Never, Seldom, Sometimes, Often, and Almost Always are scored on a five-point basis.

3.5.5 Assessing Achievement in Phase 1

Because the method of assessing achievement in Phase 1 was considered satisfactory, there was no need to assess achievement again in Phase 2. Therefore this section pertains to Phase 1 only.

The multiple-choice mathematics achievement test developed by the researcher included 25 items and was used only in Phase 1 of the study. Its content consisted of problems based on the five mathematical strands tested on the Florida Comprehensive Assessment Test (FCAT). The items were written at a specific grade level and students were instructed to choose and bubble in the correct response on a ParScore Test Form, developed by Economics Research, Inc. (1990) and distributed by Scantron Cooperation. Items on the test were based on ones given as samples for practice from the Florida Department of Education (DOE), and the Miami-Dade County Public Schools (MDCPS) Testing and Evaluation department. The sample items were also used as instruction during the nine week period. The teachers were encouraged to generate problems similar to the sample items and use the students' prior knowledge and real world situations to simulate these problems.

3.6 Data Analysis

Fraser (1986b) discussed the important issue of choosing an appropriate unit of statistical analysis. He stated four reasons for the need to choose an appropriate unit of statistical analysis. First, with the use of different units of statistical analysis, variables with the same operational definition could have different substantive interpretations. Secondly, there is the possibility that the relationships found by using a particular unit of statistical analysis could differ in size and even in sign from those obtained using another unit of analysis (Robinson, 1950). Thirdly, there is the possibility of violating the condition of independence of observations, and hence the validity of statistical significance tests, resulting from the use of certain units of statistical analysis (Peckham, Glass & Hopkins, 1969; Ross, 1978). And, finally, using different units of statistical analysis could mean the testing of conceptually-different hypotheses (Burstein, Linn, & Capell, 1978).

The two most-commonly used units of statistical analysis in prior classroom environment research have been the individual student and class mean, although some studies have used the school mean (Brookover, Schweitzer, Schneider, Beady, Flood and Wisenbaker, 1978), the mean of subgroups of students within the class (Walberg, Singh & Rasher, 1977) or the deviation of a student's score from the class mean (Sirotnik, 1980). For the purpose of this study and in line with past research, the two units of analysis chosen for most analyses were the individual student score (between-student analyses) and the class mean score (between-class analysis).

My methods of data analysis are discussed below in relation to my study's three research questions involving validation of questionnaires (Section 3.6.1), evaluation of the use of hands-on manipulatives in mathematics (Section 3.6.2) and investigation of outcome-environment associations (Section 3.6.3).

3.6.1 Validation of Instruments in Phase 1 and 2

My first research question sought to examine whether it was possible to develop and validate suitable measures of a) classroom environment and b) student attitudes towards mathematics. Section 3.6.1 describes the three types of validation analyses: factor and item analyses to check the structure of questionnaires; reliability and discriminant validity analyses; and ANOVA to test whether environment scales could differentiate between the perceptions of students in different classrooms.

3.6.1.1 Factor and Item Analyses

Factor and item analysis were undertaken with the objective of refining the instruments and providing evidence of their validity and reliability. The method used widely to improve scale internal consistency is to remove any item which is not reasonably well correlated with the total score for its scale. To check the factor structure of each of the three classroom environment instruments (MCI, SLEI and QTI) used in Phase 1 of this study, a separate principal components factor analysis with varimax rotation was conducted for each questionnaire. Because the sample was too small to conduct factor analysis separately for Grades 4 and 5, the two samples were combined ($N = 442$).

A second phase to this study involved a sample of 375 Grades 4 and 5 students in four elementary schools in the Miami-Dade County Public Schools (MDCPS) district. This became necessary for a number of reasons already outlined in Section 3.2. To overcome weakness in the classroom environment questionnaires in Phase 1, I modified the What Is Happening In this Class? (WIHIC) to four scales and 29 questions for use in Phase 2. Factor analysis was again used to check the structure of the WIHIC.

To determine the factorial validity of the Test Of Mathematics-Related Attitudes (TOMRA), factor analysis with varimax rotation was carried out separately for the pretest and posttest data and separately for Phases 1 and 2. Only two eight-item scales, Adoption of Mathematical Attitudes and Enjoyment of Mathematics Lessons, were used in this phase of my study. The TOMRA was administered as an online survey in Phase 2 in order to minimize the time students had to devote to completing the questionnaires.

3.6.1.2 Reliability and Discriminant Validity of Refined Scales

Various techniques were used to test the reliability of each scale in each classroom environment and attitude instrument in both Phase 1 and Phase 2 of my study. Internal consistency reliability of a scale is a measure of the extent to which the items in a scale assess the same construct. This characteristic was assessed using Cronbach's (1951) alpha coefficient for each of the five classroom environment scales in Phase 1, the four WIHIC scales in Phase 2, and two TOMRA scales in both phases. Reliabilities were estimated for Grades 4 and 5 and the combined sample in Phase 1 and, in the case of the MCI, separately for the actual and preferred forms. The internal consistency reliability of each scale was determined two units of analyses, namely, the individual and the class mean.

The discriminant validity (using the mean correlation of a scale with the other scales) was also calculated for each questionnaire in Phases 1 and 2. Both the individual and class mean were used as the units of analysis.

3.6.1.3 ANOVA for Differences Between Classrooms

A one-way ANOVA was used for the actual form of each scale of the classroom environment instruments used in Phase 1 and Phase 2, with class membership as the main effect and using the individual student as the unit of analysis, to examine whether there was differentiation between students' perceptions in different classes. Usually students within the same class should perceive a classroom environment relatively similarly, while the class mean should vary from classroom to classroom.

The common indices used in this case are ANOVA results such as the significance level and eta² statistic, which is the ratio of 'between' to 'total' sums of squares and indicates the proportion of variance explained by class membership.

3.6.2 Analyses for the Effectiveness of Using Hands-on Manipulatives

The main purpose of my study was to evaluate the effectiveness of using hands-on manipulatives in improving classroom environment, attitudes and achievement among elementary school mathematics students in Miami-Dade County, Florida, USA. A mathematical manipulative is defined as any material or object from the real world that children move around to show a mathematics concept. They are concrete, hands-on models that appeal to the senses and can be touched by students. For Phase 1 of my study, differences between an experimental group (that used manipulatives for 60% of the time) and a control group (that used manipulatives for less than 40% of the time), were described in terms of the effect size (magnitude of the difference) and its statistical significance (*t* test for each learning environment, attitude, and achievement scale). For Phase 2, the WIHIC and TOMRA questionnaires were administered as a pretest and posttest to the students. Differences between the pretest and posttest for the set of six dependent variables (Student Cohesiveness, Teacher Support, Task Orientation, Cooperation from the WIHIC and Adoption of Mathematical Attitudes and Enjoyment of Mathematics Lessons for the TOMRA) were analyzed in Phase 2 using a MANOVA for repeated measures to test the statistical significance of changes overall of the set of six learning environment and attitude scales. Effect sizes were used to describe the magnitude, as distinct from the statistical significance, of pre-post changes on each of the six scales.

3.6.3 Simple Correlation and Multiple Regression Analyses for Outcome-Environment Associations

My third research question was whether there were relationships between classroom environment and students' achievement and students' attitudes towards mathematics. To achieve these aims for Phase 2 of my study, two types of analyses were done, namely, simple correlation and multiple regression analyses using data from the WIHIC and the TOMRA. Simple correlation was calculated to determine the extent to which each WIHIC scale is associated with each individual attitudinal scale in the TOMRA. Multiple regression analyses were also undertaken to give information about the joint influence of correlated scales in the WIHIC on attitude for the two scales of TOMRA, namely, Adoption of Mathematical Attitudes and Enjoyment of Mathematics Lessons. The multiple correlation describes the joint influence of the set of environment scales on each outcome, whereas the standardized regression coefficient (beta) provide information about whether an environment scale is independently associated with an outcome when the other environment scales are mutually controlled. The magnitudes of environment-outcome relationships were compared for two units of analysis, namely, the individual and class mean.

In order to investigate the research question about associations between the nature of the classroom environment and the two outcomes of achievement and attitudes in Phase 1 of my study, similar simple correlation and multiple regression analyses were used.

3.7 Quantitative and Qualitative Approaches

Most of the early research studies into classroom environments were quantitative in nature (Newby & Fisher, 1997) and involved the development and use of a number of instruments. Significant progress has been made towards the desirable goal of combining qualitative and quantitative methods within the same study in research on classroom learning environment (Fraser & Tobin, 1991; Tobin & Fraser, 1998). The main data-collection methods used in my study involved quantitative assessment of students' achievement, attitudes and perceptions of classroom environments.

The quantitative research approach involved investigating whether achievement, learning environment, and attitudes improved when hands-on manipulatives were utilized. The quantitative research approach readily allows the establishment of relationships among variables. The qualitative research approach helps to explain factors underlying the broad relationships that were established. Arsenault and Anderson (1998) supported the view that qualitative research is an inductive form of inquiry, in which the subjects are in a classroom setting and multi-methods are used to interpret, understand, explain and bring meaning to the interpretation of the data.

Qualitative research methods were developed in the social sciences to enable researchers to study social and cultural phenomena. Examples of qualitative methods are action research, case study research and ethnography. Qualitative data sources include observation and participant observation (fieldwork), interviews and questionnaires, documents and texts, and the researcher's impressions and reactions. Qualitative research methods are designed to help researchers to understand people and the social and cultural contexts within which they live (Myers, 1997). Significant progress has been made in using qualitative methods in learning environment research and in combining quantitative and qualitative methods within the same study of classroom environments (Fraser & Tobin, 1991; Tobin & Fraser, 1998).

The use of quantitative methods has tended to dominate Asian research on learning environments. Quite a few Asian studies have used qualitative methods in a minor way, such as interviews of a small group of students aimed at checking the suitability of learning environment questionnaire and modifying it before using it in a large-scale study (e.g., Khine, 2001; Margianti et al., 2001a, 2001b; Soerjaningsih et al., 2001a, 2001b). For example, in Brunei, Khine and Fisher (2001, 2002) conducted a pilot study in which students were interviewed concerning difficulties experienced in responding to classroom environment surveys. Also, in Singapore, Khoo and Fraser (1998) randomly selected 46 students for interviews in order to cross-check students' questionnaire responses and to obtain richer insights into students' perceptions of their classroom environments.

Qualitative methods were used sparingly in my study when modifying and trying out the questionnaires. For Phase 1, the researcher interviewed individual students from fourth and fifth grade classes about whether they understood the wording and what the questions meant to them. Their answers helped in the modification of the questionnaires. In Phase 2 of the study, which involved administering two questionnaires the Grade 4 and 5 students in the four elementary schools, no interviews with individual students about modifications and no other qualitative information was collected. The absence of more comprehensive qualitative research methods in my study is a shortcoming that should be rectified in future research.

3.8 Summary

This chapter described the research methods, sample sizes, procedures for collecting data, survey instruments, and how data were analyzed.

Overall, my study's three main goals were to find out: whether it is possible to develop and validate suitable measures of classroom environment and student attitudes towards mathematics; whether the use of hands-on manipulatives is effective in providing improvements in achievement, attitude and classroom environment; and, lastly, whether there are relationships between classroom environment and students' achievement and students' attitude towards mathematics.

The three survey instruments that were chosen to measure student perceptions of classroom learning environment instruments in Phase 1 were the My Class Inventory (MCI), Science Laboratory Environment Inventory (SLEI) and Questionnaire on Teacher Interaction (QTI). Also another questionnaire in Phase 1 was designed to measure students' attitudes towards mathematics in an elementary classroom setting. Items in the questionnaire were modified from Fraser's (1981b) Test Of Science-Related Attitude (TOSRA), which was designed to measure science-related attitudes among secondary school students. Also achievement in mathematics was assessed in Phase 1 only.

Phase 2 utilized two modified instruments. The What Is Happening In this Class? (WIHIC) was used as an improved measure of classroom environment. In Phase 1, two scales from the Test Of Science-Related Attitudes (TOSRA) were modified to form the Test Of Mathematics-Related Attitudes (TOMRA).

Phase 1 of study involved a sample of 442 students in 9 fourth and 9 fifth grade classes and their 18 teachers in a predominantly Hispanic elementary school in the Miami-Dade County Public Schools (MDCPS) district in Florida, United States. A total of 375 Grade 4 and 5 students in 4 elementary schools with 20 teachers (11 fourth and 9 fifth grades) in the Miami-Dade County Public Schools (MDCPS) district participated in Phase 2 of my study.

Validation of the survey instruments were carried out by using item and factor analysis. Factor analysis was used to check the structure or factorial validity of instruments. Cronbach's alpha coefficient was used as a measure of each scale's internal consistency reliability. Also ANOVA was used for the actual form of each scale of the classroom environment instruments used in Phase 1 and Phase 2 to determine whether it could differentiate between the perceptions of students in different classrooms.

The instruments were modified for elementary students by shortening the number of items and changing some of the wording to suit the needs of the students who mostly speak English as a second language. Some difficulties were experienced during the data collection. Of the 612 sets of questionnaires distributed for each instrument in Phase 1, only 442 complete questionnaires were obtained for use in the analyses. For

Phase 2 of the study, an online survey was administered to the participants using SurveyGold. It is assumed that, because of the poor reading levels of the Exceptional Student Education students in both grades and the time that was allotted to administer the instruments, some students were unable to complete the questionnaires.

The second research objective involved the evaluation of the use of hands-on manipulatives in providing improvement in terms of achievement, attitudes and classroom environment. In Phase 1 of my study, there were two instructional groups: one group used hands-on manipulatives for more than 60% of the instructional time; the other group used hands-on manipulatives for 40% or less of the instructional time. Differences between these two instructional groups were described in terms of effect sizes (magnitude of the difference) and their statistical significance using *t* tests for paired samples for Phase 1 of my study.

A MANOVA for repeated measure was conducted to test the statistical significance of changes overall for a set of six learning environment and attitude scales during the interval between pretest and posttest. The magnitude of the difference between pretest and posttest scores for the six dependent variables in Phase 2 (four WIHIC and two TOMRA scales) were reported using effect sizes.

Lastly, associations between students' perceptions of their classroom learning environment and student outcomes (attitudes and achievement) were investigated in both phases using simple correlation and multiple regression analyses for two levels of analysis, namely, the student and the class. For example, in Phase 2 of my study, data from four scales of the WIHIC were selected and two attitude scales from the TOMRA were analyzed. Multiple regression analyses were also undertaken to give information about the joint influence of correlated WIHIC scales on attitudes for the two scales of TOMRA The multiple correlation describes the joint influence of the set of environment scales on each outcome, whereas the standardized regression coefficient provides information about which environment scale is independently associated with an outcome when the other environment scales are mutually controlled. For associations between the nature of the classroom environment and the two outcomes of achievement and attitudes in Phase 1 of my study, similar simple correlation and multiple regression analyses were undertaken.

A major weakness of my study was the limited use of qualitative research methods, which were used a little in Phase 1 when the questionnaires were being modified, but not at all in Phase 2. This limitation should be rectified in future research.

CHAPTER 4

DATA ANALYSES AND FINDINGS

4.1 Introduction

As previously delineated in Chapter 1, the major aims of this research, involved, first, validation of measures of classroom environment and students' attitudes toward mathematics, second, an evaluation the use of hands-on manipulatives in terms of classroom environment and students' attitudes and achievement and, third, investigation of relationships between classroom environment and students' attitudes and achievement.

This study was conducted in two separate phases. In Phase 1, two instructional groups using manipulatives to different degrees were compared. To accomplish this, I utilized an achievement test, an attitude scale and three learning environment questionnaires that were modified to suit elementary students. The learning environment instruments that were modified and used were the My Class Inventory (MCI), Science Laboratory Environment Inventory (SLEI), and Questionnaire on Teacher Interaction (QTI). Attitudes to mathematics were assessed with a scale based on the Test Of Science-Related Attitude (TOSRA) that I modified for mathematics. I adapted eight items from the TOSRA's Enjoyment of Science Lessons scale to assess the extent to which students in my sample were satisfied with and looked forward to their mathematics classes.

There were several reasons for undertaking a second phase to my study. First, in the first phase of the study, it proved difficult to establish strong validity and reliability for the classroom learning environment instruments used (the My Class Inventory, MCI, Science Laboratory Environment Inventory, SLEI, and Questionnaire on Teacher Interaction, QTI). Some weaknesses were experienced because most of the students spoke English as a second language, because wording of the instruments was modified, and because I reduced the number of items per scale to facilitate the reading demands on students. Therefore, the well-established classroom environment questionnaire, What Is Happening In this Class? (WIHIC), was used in Phase 2 with an adequate number of items per scale.

In Phase 1, attitudes were measured with eight items selected from and modified the Enjoyment of Science Lessons scale of the Test Of Science-Related Attitudes (TOSRA) to form the Test Of Mathematics-Related Attitudes (TOMRA). The choice of TOMRA items for Phase 1 also showed some weaknesses. Some students were unable to read the items on the questionnaires and others were unable to answer all the questions in the allotted time because of the readability of the instruments for students whose native language was not English. Therefore, in Phase 2, TOMRA was modified to 16 items in two scales.

Phase 1 of the study suffered because the planned sample size shrank for various reasons: ESE student population, reading levels of students, etc. To compensate for this, a new sample of a more reasonable size that extended beyond a single school was used. A sample of 422 Grades 4 and 5 students in one elementary school in the Miami-Dade County Public Schools (MDCPS) district participated in Phase 1 of my study. For Phase 2, a representative sample of 375 students in Grades 4 and 5 in four elementary schools in the same diverse school district participated in the study.

A pre-post design for the WIHIC and TOMRA was used in Phase 2 to monitor changes in learning environment and student attitudes during students' use of hands-on manipulatives. The second objective of this study was to find out whether the use of hands-on manipulatives is effective in terms of achievement, attitudes, and classroom environment. In Phase 1, I compared an experimental and a control group in terms of achievement, attitude and classroom environment perceptions. The experimental group used manipulatives for at least 60% of all the mathematical strands activities covered in that class/section. The control group used hands-on manipulatives for an average of less than 40% of the time on all mathematical strand activities in their class/section. Both groups were instructed using strategies designed by the Florida Department of Education (DOE) and the Miami-Dade County Public Schools (MDCPS) district.

Phase 2 of my study was intended to overcome some weaknesses apparent in Phase 1. Therefore, a questionnaire was administered to students as both a pretest and a posttest in four other elementary schools with similar population over one grading period (nine-weeks) in the Miami-Dade County Public Schools (MDCPS) district. For Phase 2 of my study, the second research question involved evaluating the use of hands-on manipulatives in terms of student attitudes and classroom learning environment (for Phase 2 achievement was not utilized). Students were encouraged to use manipulatives whenever they desired, as the manipulative kits were placed on their desks and if their textbook instructed to use them.

The structure of headings and subheadings in Chapter 4 is overviewed below:

4.2 Validity and Reliability of Classroom Environment and Attitude Scales

My study's first research question involved validation of:

- three learning environment questionnaires in Phase 1 (My Class Inventory, MCI, Questionnaire on Teacher Interaction, QTI, and Science Laboratory Environment Inventory, SLEI)
- the What Is Happening In this Class? (WIHIC) in Phase 2
- the Test of Mathematics-Related Attitudes (TOMRA) in Phase 2.

4.2.1 Factorial Validity of Questionnaires

Factor analysis was used to check whether the *a priori* structure of the multiscale instruments used in my study could be replicated with my sample of elementary school students in Florida. For each questionnaire, a principal components factor analysis (with varimax rotation and Kaiser normalization) was undertaken. The criteria for the retention of any item in each factor analysis was that its factor loading was at least 0.40 on its a *priori* scale and less than 0.40 on all other scales in that instrument.

For my study, the following series of factor analyses was conducted to check the *a priori* structure of various questionnaires:

- each of three separate classroom environment questionnaires used in Phase 1 (MCI, QTI and SLEI) with a sample of 422 students (Section 4.2.1.1)
- the WIHIC classroom environment questionnaire used in Phase 2 with a sample of 375 students (Section 4.2.1.2)
- the version of the TOMRA attitude questionnaire used in Phase 2 with 375 students (Section 4.2.1.3).

4.2.1.1 Factorial Validity of MCI, QTI and SLEI in Phase 1

In order to check the factor structure of each of the three classroom environment instruments used in Phase 1 – My Class Inventory (MCI), Questionnaire on Teacher Interaction (QTI), and the Science Laboratory Environment Inventory (SLEI) – a separate principal components factor analysis with varimax rotation was conducted for each questionnaire. For the MCI, factor analyses were conducted only for the actual form (and not for the preferred form). Because the sample was too small to conduct factor analysis separately for Grades 4 and 5, the two samples were combined ($N = 442$).

The original version of the My Class Inventory (MCI) in Appendix C had 25 items in the 5 scales of Student Cohesiveness, Friction, Satisfaction, Difficulty, and Competitiveness. The version of the Questionnaire on Teacher Interaction (QTI) used in my study Appendix E had 24 items assessing the 4 scales of Leadership, Understanding, Uncertain and Admonishing behavior. The original version of the Science Laboratory Environment Inventory (SLEI) in Appendix D had 35 items in the 5 scales of Student Cohesiveness, Open-Endedness, Investigation, Rule Clarity and Material Environment.

TABLE 4.1 Factor Analysis Results for the My Class Inventory (MCI)

Item	Factor Loading	
	Friction	Competition
2	0.63	
6	0.74	
7		0.63
9		0.65
11	0.74	
12		0.61
13		0.59
14	0.68	
15		0.47
% Variance	23.34	20.24

The sample consisted of 442 students.
Only factor loadings greater than 0.40 are recorded.

Because of the small number of items per scale – 15 items in 5 scales for the My Class Inventory (MCI), 12 items in four scales for the Questionnaire on Teacher Interaction (QTI), and 15 items in five scales for the Science Laboratory Environment Inventory (SLEI) – it was not possible to replicate the *a priori* factor structure of each instrument.

TABLE 4.2 Factor Analysis Results for the Questionnaire on Teacher Interaction (QTI)

Item	Factor Loading	
	Leadership/Understanding	Uncertain/Admonishing
1	0.41	
2	0.68	
3		0.52
4		0.55
5	0.47	
6	0.53	
7		0.72
9	0.69	
11		0.59
12		0.46
% Variance	17.83	17.08

The sample consisted of 442 students.
Only factor loadings greater than 0.40 are recorded.

Tables 4.1 to 4.3 in Phase 1 show the optimal factor structure for each instrument. This table only includes items whose factor loading is at least 0.40 with its own scale and less than 0.40 with any other scale(s). These tables show that the optimal factor structure consists of:

- For the MCI, nine items in two factors called Friction and Competition which account for 43.58% of the variance (see Table 4.1).
- For the QTI, 10 items in two scales called Leadership/Understanding and Uncertain/Admonishing teacher behaviour which account for 34.91% of the variance (see Table 4.2). The two *a priori* scales with a positive connotation came together into one factor, and the two *a priori* scales with a negative connotation came together.
- For the SLEI, eight items in a single scale called Individualization which accounts for 30.01% of the variance (see Table 4.3).

TABLE 4.3 Factor Analysis Results for the Science Laboratory Environment Inventory (SLEI)

Item	Factor Loading
	Individualization
1	0.55
2	0.40
7	0.46
8	0.50
9	0.66
11	0.63
12	0.50
15	0.64
% Variance	30.01

The sample consisted of 442 students.
Only factor loadings greater than 0.40 are recorded.

4.2.1.2 Factorial Validity of WIHIC in Phase 2

In order to overcome weaknesses with the learning environment questionnaires that emerged during Phase 1 of my study, I chose the widely-used What Is Happening In this Class? (WIHIC) questionnaire for Phase 2.

The original version of the What Is Happening In this Class? (WIHIC) consists of 7 scales and 56 items (Fraser, Fisher, & McRobbie, 1996; Aldridge & Fraser, 1997). The seven scales are Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation and Equity. However, the questionnaire was modified for use in my study with elementary school students in Grades 4 and 5 in the Miami-Dade County Public Schools (MDCPS) district. Only five of the seven original scales were utilized in my study: Student Cohesiveness, Teacher Support, Involvement, Task Orientation, and Cooperation. Investigation and Equity were not used in my study because the questionnaire would be too long for use with Grades 4 and 5 students. All 8 items in each scale were retained. However, some questionnaire items were modified. For example, the word ‘pupil’ was changed to ‘students’ to suit the reading abilities of the students. The version of the WIHIC used in my study contained 40 items which the students completed online using SurveyGold software (copyright © 1998–2005 Golden Hills Software, Inc.). This program helps to create and conduct paper, telephone, and Web surveys. This software was utilized in my study because the researcher felt that its use would enable students to take less time to respond to items. Because the time allotted to mathematics in an elementary school is limited to one hour, the students needed to complete the questionnaire within that time frame in order to submit to SurveyGold in one session. The program allows the students, on completion of the survey, to submit their answers immediately to the SurveyGold database. The easy access to the data on Excel for analysis was another reason for choosing this software program. A copy of the version of the WIHIC used in my study is provided in Appendix G.

To determine the factorial validity of the WIHIC questionnaire, factor analysis with varimax rotation was performed for data from the 375 students in 20 classes in Phase 2 of this study. Table 4.4 provides the factor loadings for the WIHIC separately for pretest and posttest administrations.

During the factor analysis, the criteria used for retention of any item were that its factor loading needed to be at least 0.30 on its *a priori* scale and less than 0.30 on all other scales. The application of these criteria led to an optimal factor solution with 29 items in four scales (see Table 4.4). The original scale of Involvement was lost altogether and three items (namely, Items 2, 3, and 8) were lost from the Student Cohesiveness scale. All of the original eight items were retained in Teacher Support, Task Orientation and Competition.

Table 4.4 shows that there were three cases for which a WIHIC item's factor loading was less than 0.30 with its own scale (namely, Items 5 and 6 on the Student Cohesiveness scale for the pretest and Item 37 on Cooperation for the posttest). The total percentage of variance ranged from 5.26% to 8.29% for different scales for the pretest and from 5.25% to 25.36% for different scales for the posttest (Table 4.4). The total percentage of variance explained by the 29 items in four scales was 45.87% for the pretest and 43.98% for the posttest. The eigenvalues for the WIHIC scales ranged from 1.53 to 7.36 for the pretest and from 1.55 to 7.17 for the posttest.

TABLE 4.4 Factor Analysis Results for the WIHIC

Item	Factor Loadings							
	Student Cohesiveness		Teacher Support		Task Orientation		Cooperation	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	0.73	0.53						
4	0.53	0.72						
5	–	0.31						
6	–	0.34						
7	0.50	0.50						
9			0.57	0.38				
10			0.69	0.55				
11			0.46	0.45				
12			0.59	0.60				
13			0.59	0.63				
14			0.55	0.57				
15			0.58	0.38				
16			0.46	0.49				
25					0.65	0.65		
26					0.55	0.55		
27					0.53	0.61		
28					0.54	0.62		
29					0.63	0.58		
30					0.63	0.54		
31					0.59	0.60		
32					0.38	0.46		
33							0.51	0.46
34							0.43	0.47
35							0.46	0.42
36							0.55	0.38
37							0.58	–
38							0.71	0.69
39							0.63	0.58
40							0.62	0.50
% Variance	5.26	5.35	6.96	6.21	25.36	7.70	8.29	24.72
Eigenvalue	1.53	1.55	2.02	1.80	7.36	1.23	2.40	7.17

The sample consisted of 375 students in 20 classes.
Factor loadings smaller than 0.30 have been omitted.
Items 2, 3, and 8 were omitted.

Although it was difficult in Phase 1 to find strong support for the factorial validity of the MCI, QTI and ICEQ, the results in Table 4.4 provide strong support for the factorial validity of the WIHIC.

4.2.1.3 Factorial Validity of TOMRA in Phase 2

The Test Of Mathematics-Related Attitudes (TOMRA) was modified from the Test Of Science-Related Attitudes (TOSRA) for use in Phase 2 of my study. Only two eight-item scales, Adoption of Mathematical Attitudes and Enjoyment of Mathematics Lessons, were utilized in my study. The original 70-item TOSRA was too long for the students in Grades 4 and 5. Therefore, it was modified to two scales which were administered as an online survey in order to minimize the time that students had to devote to completing the questionnaires.

Some questions were phrased in a negative fashion, which required reverse scoring of the responses in order to determine a scale score for a factor. A complete copy of the instrument can be found in Appendix G. An online survey was used to administer the instrument to the Grades 4 and 5 students in Phase 2 of my study.

To determine the factorial validity of the Test Of Mathematics-Related Attitudes (TOMRA), factor analysis with varimax rotation was carried out for the 16 items in two scales. Table 4.5 provides the factor loadings for the TOMRA separately for the pretest and posttest data. The sample consisted of 375 students in 20 classes in Grades 4 and 5 in the Miami-Dade County Public Schools (MDCPS) district, South Florida.

All 16 TOMRA items were retained in both scales. Each of the 16 TOMRA items had a factor loading of at least 0.30 on its own scale and less than 0.30 on the other scale for both the pretest and posttest data (Table 4.5). The percentage of variance for the Adoption of Mathematical Attitudes scale was 13.10% for the pretest and 14.27% on the posttest. The percentage of variance for the Enjoyment of Mathematics lessons scale was 38.88% for the pretest and 43.16% for the posttest. The total percentage of variance accounted for by the two attitude scales was 51.98% for the pretest and 57.43% for the posttest. The eigenvalue for the Adoption of Mathematical Attitudes was 2.10 for the pretest to 2.28 for the posttest, and for the Enjoyment of Mathematics lessons scale was 6.22 for the pretest and 6.91 for the posttest (Table 4.2).

TABLE 4.5 Factor Analysis Results for the TOMRA

Item	Factor Loadings			
	Adoption of Mathematical Attitudes		Enjoyment of Mathematics Lessons	
	Pre	Post	Pre	Post
41	0.60	0.56		
42	0.38	0.46		
43	0.49	0.42		
44	0.53	0.64		
45	0.57	0.68		
46	0.41	0.46		
47	0.51	0.62		
48	0.55	0.63		
49			0.72	0.76
50			0.71	0.87
51			0.66	0.69
52			0.78	0.89
53			0.82	0.84
54			0.82	0.88
55			0.81	0.74
56			0.77	0.79
% Variance	13.10	14.27	38.88	43.16
Eigenvalue	2.10	2.28	6.22	6.91

The sample consisted of 375 students in 20 classes.
Factor loadings smaller than 0.30 have been omitted.

Overall, the results reported in Table 4.2 Phase 2 provide strong support for the factorial validity of the 16 item two-scale version of TOMRA used in my study.

4.2.2 *Internal Consistency Reliability and Discriminant Validity*

Internal consistency is a measure of the extent to which the items in a scale assess the same construct. This characteristic was assessed using Cronbach's alpha coefficient. In contrast, discriminant validity is a measure of the independence of different scales within the same instrument. In the following tables, the mean correlation of a scale with the other scales in the same instrument is used as a convenient index of discriminant validity.

In Section 4.2.2, the internal consistency reliability and discriminant validity is reported for different instruments in four subsections:

- internal consistency reliability for the five learning environment scales of Friction and Competition (both actual and preferred forms) and actual Leadership/Understanding, Uncertain/Admonishing and Individualization for the sample of 237 Grade 4 students and 205 Grade 5 students in Phase 1 (Section 4.2.2.1)

- internal consistency reliability of attitude and achievement measures for the sample of 237 Grade 4 students and 205 Grade 5 students in Phase 1 (Section 4.2.2.2)

- internal consistency reliability and discriminant validity for pretest and posttest data for the WIHIC (Student Cohesiveness, Teacher Support, Task

Orientation and Cooperation) for two units of analysis (student and class mean) for a sample of 375 students in 20 classes in Phase 2 (Section 4.2.2.3).

4.2.2.1 *Internal Consistency Reliability of Classroom Environment Scales in Phase 1*

In Phase 1, the reliability was assessed for each of the five classroom environment scales identified in the factor analyses reported in Tables 4.1–4.3. Reliabilities were estimated separately for Grade 4, Grade 5 and the combined sample and, in the case of the MCI, separately for the actual and preferred forms. The sample size was 237 in Grade 4 and 205 in Grade 5. The student was used as the unit of statistical analysis.

TABLE 4.6 Internal Consistency Reliability (Cronbach Alpha Coefficient) and Ability to Differentiate Between Classrooms (ANOVA Results) for Five Classroom Environment Scales

Scale	Alpha Reliability			ANOVA (Eta^2)
	Grade 4	Grade 5	Combined	Combined
My Class Inventory (MCI)				
Actual Friction	0.51	0.70	0.67	0.29**
Preferred Friction	0.50	0.69	0.64	
Actual Competition	0.50	0.55	0.57	0.08**
Preferred Competition	0.54	0.66	0.62	
Questionnaire on Teacher Interaction (QTI)				
Leadership/Understanding	0.50	0.59	0.54	0.13**
Uncertain/Admonishing	0.52	0.50	0.51	0.13**
Science Laboratory Environment Inventory (SLEI)				
Individualization	0.57	0.59	0.64	0.35**

The sample consisted of 237 Grade 4 students and 205 Grade 5 students.
Eta^2 is the ratio of between to total sums of squares. It represents the proportion of variance explained by class membership.

Table 4.6 of my study shows that alpha reliabilities in Phase 1 range from 0.50 to 0.57 for the Grade 4 sample, from 0.50 to 0.70 for the Grade 5 sample, and from 0.51 to 0.67 for the combined sample. Although the reliability values for some scales are not high, all values can be considered minimally satisfactory given the short length of scales (ranging from 4 to 8 items). However, in Phase 2 of my study, I used a different learning environment questionnaire so that better reliability could be achieved.

4.2.2.2 Internal Consistency Reliability of Attitude and Achievement Measures in Phase 1

To measure student attitudes in Phase 1 of the study, I selected eight items from the Enjoyment of Science Lessons scale in the Test of Science-Related Attitudes (TOSRA, Fraser, 1981) and modified them for mathematics. In order to assess student achievement, a 25-item multiple-choice test was developed by me and patterned after the ones tested on the Florida Comprehensive Achievement Test (FCAT). Students were instructed to choose and bubble in the correct response on a ParScore Test Form, developed by Economics Research, Inc. (1990) and distributed by Scantron Cooperation. Items on the test were based on ones given as samples for practice from the Florida Department of Education (DOE), and the Miami-Dade County Public Schools (MDCPS) Testing and Evaluation department.

Table 4.7 reports the internal consistency reliability of the outcome measures (attitudes and achievement) used in Phase 1 of my study. Reliabilities are shown separately for Grade 4 and Grade 5 and separately for pretest and posttest for the achievement measures in Phase 1 of my study. Note that, in order to improve the internal consistency reliability, four items were omitted from the Grade 4 achievement test and three items were omitted from the Grade 5 achievement test. Reliabilities can be considered satisfactory (0.61–0.86) for scales containing a relatively small number of items.

TABLE 4.7 Internal Consistency Reliability (Cronbach Alpha Coefficient) for Attitude and Achievement Measures

Outcome	Alpha Reliability	
	Grade 4	Grade 5
Attitudes	0.80	0.86
Pretest Achievement	0.61	0.64
Posttest Achievement	0.62	0.71

Items 3, 4, 6, 13 and 23 were omitted from the Grade 4 achievement test.
Items 1, 2, 4 and 7 were omitted from the Grade 5 achievement test.
Sample consisted of 237 Grade 4 students and 205 Grade 5 students.

4.2.2.3 Internal Consistency Reliability and Discriminant Validity for the WIHIC in Phase 2

As reported earlier in Table 4.4, for the What Is Happening In this Class? questionnaire administered in Phase 2 of my study, 29 items in four scales survived the factor analysis. The internal consistency reliability (Cronbach alpha coefficient) for each of these four WIHIC scales was determined for the student sample of 375 students. In line with past research, all reliability analyses were performed for two units of analysis (namely, the student and the class). Table 4.8 reports the reliability of each WIHIC scale separately for pretest and posttest data and for the two units of analysis.

Internal consistency reliability (alpha coefficient) for different WIHIC scales ranged from 0.65 to 0.82 on the pretest and from 0.68 to 0.81 on the posttest with the student as the unit of analysis scale. Table 4.8 shows that the reliability for different scales ranged from 0.67 to 0.85 for the pretest and 0.69 to 0.88 for the posttest with the class as the unit of analysis. As expected, reliabilities are higher when the class mean is used as the unit of analysis (Fraser, 1994).

TABLE 4.8 Internal Consistency Reliability (Cronbach Alpha Coefficient), Discriminant Validity (Mean Correlation with Other Scales) and Ability to Differentiate Between Classrooms (ANOVA Results) for Pretest and Posttest Administrations of the WIHIC and TOMRA

Scale	No. of Items	Unit of Analysis	Alpha Reliability		Correlation with Other Scale		ANOVA Eta^2	
			Pre	Post	Pre	Post	Pre	Post
WIHIC								
Student Cohesiveness	5	Student	0.65	0.68	0.40	0.39	0.08*	0.05
		Class	0.67	0.69	0.34	0.38		
Teacher Support	8	Student	0.82	0.79	0.42	0.43	0.05	0.06
		Class	0.72	0.79	0.28	0.38		
Task Orientation	8	Student	0.80	0.81	0.39	0.39	0.08	0.08*
		Class	0.85	0.88	0.27	0.33		
Cooperation	8	Student	0.82	0.71	0.43	0.45	0.11**	0.08*
		Class	0.85	0.81	0.44	0.43		
TOSRA								
Adoption of Mathematical	8	Student	0.76	0.81	0.45	0.46	–	–
Attitudes		Class	0.90	0.84	0.48	0.49		
Enjoyment of Mathematics	8	Student	0.92	0.94	0.45	0.46	–	–
Lessons		Class	0.95	0.95	0.48	0.49		

Sample consisted of 375 students in 20 classes.
*$p<0.05$, **$p<0.01$

Discriminant validity is the extent to which a scale measures a unique dimension not covered by the other scales of the instrument. In Table 4.8, the mean correlation of a scale with the other three scales of the WIHIC is used as a convenient index of discriminant validity. Discriminant validity was calculated for two units of analysis, namely, the individual student and the class mean.

Table 4.8 shows that the mean correlation ranged from 0.39 to 0.42 for the pretest and from 0.39 to 0.45 for the posttest with the student as the unit of analysis. With the class as the unit of analysis, the mean correlation ranged from 0.27 to 0.44 for the pretest and from 0.33 to 0.43 on the posttest. These results suggest a reasonable level of independence of WIHIC scales, although there is a degree of overlap in raw scores. However, the factor analysis results in Table 4.4 support the independence of factor scores on WIHIC scales.

4.2.2.4 Internal Consistency Reliability and Discriminant Validity for TOMRA in Phase 2

The version of TOMRA used in my research was adapted from the Test of Science-Related Attitudes (TOSRA) to measure mathematics-related attitudes instead of science attitudes. Whenever the term 'science' was mentioned in TOSRA, it was replaced with the term 'mathematics'. Of the original seven scales, two were chosen for Phase 2 of my study: Adoption of Mathematics Attitudes, and Enjoyment of Mathematics Lessons. A complete copy of the instrument can be found in Appendix G. The instrument was administered as an online survey using SurveyGold.

Table 4.8 shows that the internal consistency reliabilities (alpha coefficient) for the two TOMRA were 0.76 and 0.92 for the pretest and 0.81 and 0.94 for the posttest with the student as the unit of analysis scale. The reliabilities for the two TOMRA scales were 0.90 and 0.95 for the pretest and 0.84 and 0.95 for the posttest with the class as the unit of analysis. As expected, reliabilities are higher when the class mean is used as the unit of analysis (Fraser, 1994).

The discriminant validity of the TOMRA (using the correlation between the two scales) was also calculated. The discriminant validity is the extent to which a scale measures a unique dimension not covered by the other scales of the instrument. Both the individual and class mean were used as the units of analysis. Table 4.8 shows that the correlation between the two attitude scales was 0.45 for the pretest and 0.46 for the posttest with the student as the unit of analysis. With the class as the unit of analysis, the correlation between scales was 0.48 for the pretest and from 0.49 for the posttest.

These results for the discriminant validity of the TOMRA suggest that raw scores on the two scales overlap to a degree. However, the factor analysis results reported in Table 4.2 support the independence of factor scores on the TOMRA.

4.2.3 Ability to Differentiate Between Classrooms

Another desirable characteristic of the actual form of any classroom environment instrument is that it is capable of differentiating between the perceptions of students in different classrooms. That is, students within the same class should perceive it relatively similarly, whereas mean classroom environment perceptions should vary from class to class. This characteristic was tested using an ANOVA for each environment scale, with class membership as the main effect.

Below, ability to differentiate between classrooms is reported for the five learning environment scales in Phase 1 in Section 4.2.3.1 and for the four learning environment scales in Phase 2 in Section 4.2.3.2.

4.2.3.1 Ability of Learning Environment Scales to Differentiate Between Classrooms in Phase 1

In Phase 1, the combined sample of 442 Grade 4 and 5 students was used in testing the ability of each of the five learning environment scales (see Tables 4.1–4.3) to differentiate between classrooms. Table 4.6 shows that each of the five actual classroom environment scales in Phase 1 differentiated significantly ($p<0.01$) between classrooms. The eta^2 statistic (the proportion of variance in environment scores accounted for by class membership) ranged from 0.08 to 0.35 for different scales.

4.2.3.2 Ability of WIHIC Scales to Differentiate Between Classrooms in Phase 2

A series of one-way analyses of variance (ANOVAs) was performed for scores on the four refined WIHIC scales to investigate each scale's ability to differentiate between perceptions of students in different classrooms. Analyses were performed separately for pretest and posttest data. Table 4.8 reports the result of the analyses in terms the eta^2 statistic (which is the ratio of 'between' to 'total' sums of squares and represents the proportion of variance in scale scores accounted for class by membership). The value of the eta^2 statistic ranged from 0.05 to 0.11 on the pretest and from 0.05 to 0.08 on the posttest for different scales (sees Table 3). The WIHIC was able to differentiate significantly ($p<0.05$) between the perceptions of students in different classes for two scales on both the pretest and posttest.

4.3 Evaluation of Use of Manipulatives

The second research question is:

2. Is the use of hands-on manipulatives effective in providing improvements in:
    a) classroom environment
    b) students' attitudes toward mathematics
    c) students' achievement in mathematics?

This important research question is answered below by reporting four sets of analyses of different data collected in Phase 1 or Phase 2 of my study:

- changes between pretest and posttest in achievement, reported separately for Grade 4 and Grade 5, in Phase 1 (Section 4.3.1)
- congruence between actual and preferred classroom learning environment for the MCI scales of Friction and Competition in Phase 1 (Section 4.3.2)
- comparison of two groups using hands-on activities to different degrees in Phase 1 (Section 4.3.3)
- changes between pretest and posttest on the four WIHIC learning environment scales and the two TOMRA attitude scales in Phase 2 (Section 4.3.4).

4.3.1 Pretest-Posttest Changes in Achievement in Phase 1

To assess student achievement, a 25-item multiple-choice pretest/posttest was developed by this researcher patterned after the ones tested on the Florida Comprehensive Achievement Test (FCAT). The multiple-choice items are designed to take an average of one minute per item to solve, with each item being worth one point. The test was administered in conditions similar to the actual Florida Comprehensive Assessment Test (FCAT). I used multiple-choice format to allow more questions per mathematics strand. The five strands are the ones recommended by the National Council of Teachers of Mathematics: Number Sense, Concepts and Operations; Measurement; Geometry and Spatial Sense; Algebraic Thinking; and Data Analysis and Probability.

Results are shown separately in Table 4.9 for Grade 4 and Grade 5. The average item is reported in Table 4.9 because the Grade 4 and Grade 5 achievement tests contain a different number of items. The difference between pretest and posttest scores is described in terms of both the magnitude of the difference (the effect size is the difference in means expressed in standard deviation units) and the statistical significance of differences (*t* test for paired samples). The individual student was used as the unit of analysis.

Table 4.9 shows that pretest-posttest differences are statistically significant for both the Grade 4 and the Grade 5 samples. However the magnitudes of these differences (0.17 and 0.31 standard deviations) are only of modest size. For both Grades 4 and 5, achievement improved between pretest and posttest.

TABLE 4.9 Average Item Mean, Average Item Standard Deviation, and Difference Between Pretest and Posttest (Effect Size and *t* Test for Paired Samples) for Achievement

Grade	Average Item Mean		Average Item Standard Deviation		Difference	
	Pre	Post	Pre	Post	Effect Size	*t*
Grade 4	0.48	0.51	0.16	0.17	0.17	2.10*
Grade 5	0.61	0.66	0.16	0.18	0.31	4.54**

* $p < 0.05$, ** $p < 0.01$
The number of matched responses was 237 in Grade 4 and 205 in Grade 5.

4.3.2 Congruence Between Actual and Preferred Environment in Phase 1

A pretest-posttest design was not used for classroom environment in Phase 1. However, because both actual and preferred environment were assessed with the MCI, it still was possible to use the congruence between actual and preferred environment as a measure of the effectiveness of the use of manipulatives. In Table 4.10, differences between actual and preferred MCI scores are reported separately for Grades 4 and 5 using both effect sizes (the magnitude of differences expressed in standard deviation units) and the statistical significance using paired *t* tests.

Table 4.10 shows that there is congruence between actual and preferred scores for Friction for both grade levels. But, for both Grade 4 and Grade 5, there is a statistically significant difference between actual and preferred environment for Competition. Students would prefer less Competition. Effect sizes are modest at each grade level (0.42 standard deviations for Grade 4 and 0.28 standard deviations for Grade 5).

TABLE 4.10 Average Item Mean, Average Item Standard Deviation, and Difference Between Actual and Preferred Scores (Effect Size and *t* Test for Paired Samples) for MCI Scales

Scale	Grade	Average Item Mean		Average Item Standard Deviation		Difference	
		Actual	Pref	Actual	Pref	Effect Size	*t*
Friction	Grade 4	1.19	1.18	0.24	0.22	0.04	0.32
	Grade 5	1.37	1.33	0.35	0.35	0.10	1.91
Competition	Grade 4	1.55	1.45	0.25	0.23	0.42	3.66**
	Grade 5	1.63	1.56	0.21	0.32	0.28	3.20**

*The number of matched responses was 122 in Grade 4 and 145 in Grade 5.

4.3.3 Comparison of Two Groups Using Hands-On Activities to Different Degrees in Phase 1

The final analysis for Phase 1 data involved comparing two groups of classes, namely, those using hands-on activities for at least 60% of mathematics lessons and those using hands-on activities for less than 40% of lessons. This comparison was made on all criteria, namely, mathematics achievement, attitudes to mathematics, and the five actual classroom environment scales of Friction, Competition, Leadership/Understanding, Uncertain/Admonishing, and Individualization. Table 4.11 provides a comparison of these two instructional groups on each of these seven measures in terms of the average item mean, average item standard deviation, and difference between the two instructional groups in terms of the effect size (the difference expressed in standard deviation units) and the result of a *t* test.

Although practical constraints within the school demanded that all students had the opportunity to use manipulatives to some extent in their mathematics classes, I still was able to compare students who used manipulatives to a greater extent with those who used manipulatives to a lesser extent. In fact, I divided most of the classes into two groups of approximately the same size: those which used manipulatives for the majority of lessons (i.e. more than 60%); and those which used manipulatives for the minority of the lessons (i.e. less than 40%). Therefore, a fourth way in which I interpreted the data was to compare students who used manipulatives for more than 60% of lessons with students who used them for less than 40% of lessons in terms of the classroom learning environment and students' mathematical achievement and attitudes to mathematics.

It is fully acknowledged that the definition of these two comparison groups (i.e. using manipulatives for more than 60% or less than 40% of lessons) is a weakness in my research design. One could not reasonably expect to find large differences between two groups of students who all use manipulatives but to varying degrees. However, practical constraints within the school environment necessitated this compromise.

Table 4.11 shows that differences between the two instructional groups are quite small for all scales except Friction. For the other scales, apart from Friction, the effect sizes range from only 0.01 to 0.11. This is not entirely unexpected because of the relative similarity in the definitions of the two instructional groups (in terms of using manipulatives either for more than 60% of lessons or less than 40% of lessons).

For Friction, Table 4.11 shows that the group using manipulatives for more time (60%) perceives significantly less Friction in the classroom than does the group using manipulatives for less time (40%). The effect size is approximately a quarter of a standard deviation (0.26), suggesting that the effect is moderate (rather than either large or small).

4.3.4 Pretest-Posttest Changes on WIHIC and TOMRA in Phase 2

In Phase 2 of my study, the second research question involved evaluating the use of manipulatives in terms of changes between pretest and posttest in terms of learning environment and student attitudes to mathematics. Learning environment was

TABLE 4.11 Average Item Mean, Average Item Standard Deviation, and Difference (Effect Size and *t* Test Results) Between Two Instructional Groups Using Manipulatives for Either More Than 60% or Less Than 40% in Phase 1

Outcome	Average Item Mean		Average Item Standard Deviation		Difference	
	>60%	<40%	>60%	<40%	Effect Size	*t*
Achievement	0.57	0.56	0.18	0.20	0.05	0.59
Attitude	4.13	4.04	0.76	0.80	0.11	0.90
Classroom Environment						
Friction	1.57	1.63	0.22	0.24	0.26	-2.09*
Competition	1.42	1.39	0.23	0.23	0.10	0.90
Leadership/Understanding	3.36	3.35	0.64	0.58	0.01	0.18
Uncertain/Admonishing	1.13	1.18	0.75	0.82	0.06	0.54
Individualization	3.65	3.63	0.71	0.67	0.03	0.21

* $p<0.05$
> 60% This instructional group used hands-on activities for more than 60% of mathematics lessons.
< 40% This instructional group used hands-on activities for less than 40% of mathematics lessons.

assessed with four scales in the refined version of the WIHIC (Student Cohesiveness, Teacher Support, Task Orientation, Cooperation) and two scales in the refined version of the TOMRA (Adoption of Mathematical Attitudes, Enjoyment of Mathematics Lessons). The sample of 375 students in 20 classes was used for these analyses.

Initially, a MANOVA for repeated measure was conducted to test for changes overall for the set of six learning environment and attitude scales during the interval between pretest and posttest. Because this MANOVA revealed that differences between pretest and posttest for the set of six dependent variables were statistically nonsignificant, no further analysis or interpretation was undertaken.

Effect sizes (i.e. the difference between pretest and posttest means divided by the pooled standard deviation) were used to describe the magnitudes, as distinct from the statistical significance, of pre-post changes on each of the six scales.

Table 4.12 reports the average item mean (i.e. the scale mean divided by the number of items in a scale) and average item standard deviation for each of the four learning environment scales of (Student Cohesiveness, Teacher Support, Task Orientation and Cooperation) and two attitude scales (Adoption of Mathematical Attitudes and Enjoyment of Mathematics Lessons). The effect sizes in Table 4.12 highlight the smallness of pre-post changes on all scales (less than one-tenth of a standard deviation in every case). The ANOVA result (*F* value) for each scale in the last column of Table 4.12 confirms that changes for all scales are statistically nonsignificant.

The smallness of pretest-posttest changes was unanticipated. Originally, it was thought that the experience of working with manipulatives would lead to improvements between pretest and posttest in both the classroom learning environment and student attitudes to mathematics. There are some tentative explanations for the absence of appreciable pre-post changes. First, because the period between pretest and posttest (i.e., when students experienced the use of manipulatives) was quite brief (only nine weeks), it is possible that the 'treatment' period was too short to enable the detection of changes in learning environment and attitudes. Perhaps some students remembered their answers from the pretest and simply repeated them on the posttest. Second, because the questionnaire was administered as an online survey and some students were not experienced using computers, it is possible that some students could have submitted the survey more than once, thus causing response errors.

TABLE 4.12 Average Item Mean, Average Item Standard Deviation and Pre-Post Difference (Effect Size and MANOVA for Repeated Measure) for WIHIC and TOMRA Scales

Scale	Average Item Mean		Average Item SD		Pre-Post Difference	
	Pre	Post	Pre	Post	Effect Size	*F*
WIHIC						
Student Cohesiveness	3.59	3.58	0.80	0.81	0.00	0.17
Teacher Support	3.66	3.59	0.88	0.83	0.09	1.13
Task Orientation	4.22	4.23	0.69	0.70	0.01	0.34
Cooperation	3.38	3.40	0.90	0.93	0.02	0.49
TOSRA						
Adoption of Mathematical Attitudes	3.78	3.82	0.78	0.81	0.05	0.86
Enjoyment of Mathematics Lessons	3.85	3.81	1.02	1.08	0.04	0.68

Sample consisted of 375 students in 20 classes.

4.4 Associations Between Student Outcomes and Classroom Environment

The third research question is:

3. Are there relationships between classroom environment and:
   a) students' attitudes towards mathematics
   b) students' achievement in mathematics?

4.4.1 Associations Between Attitude and Achievement Outcomes and Classroom Environment in Phase 1

My third research question involved associations between students' outcomes and their perceptions of their classroom learning environment. For Phase 1, these analyses involved two outcome measures (a teacher-made achievement test and one attitude scale based on TOSRA), the five learning environment scales described in Section 4.2.2.1 (Fiction, Competition, Leadership/Understanding, Uncertain/ Admonishing, and Individualization), and a sample of 265 students. In Phase 2, the outcomes consisted of two attitude scales based on TOSRA (Adoption of Mathematical Attitude and Enjoyment of Mathematics Lessons), four learning environment scales based on the WIHIC (Student Cohesiveness, Teacher Support, Task Orientation and Cooperation), and the available sample consisted of 375 students.

Analyses were conducted separately for attitudes and achievement (posttest) and separately for Grade 4 and Grade 5 samples. The available sample of students who had provided responses to all measures was 120 in Grade 4 and 145 in Grade 5. Two types of analysis were used. Simple correlation analysis was used to describe the bivariate association between each outcome and each environment scale. Multiple regression analysis was used to describe the joint influence of the set of five environment scales on each outcome (multiple correlation). The standardized regression coefficient provided information about which environment scale is independently associated with an outcome when the other four environment scales are mutually controlled. The student was used as the unit of analysis. Results are reported in Table 4.13.

For the Grade 4 sample, the results in Table 4.13 indicate that associations with classroom environment were statistically nonsignificant for both attitudes and achievement.

For the Grade 5 sample, Table 4.13 shows that the simple correlation between attitudes and environment is statistically significant ($p<0.05$) for all five environment

TABLE 4.13 Simple Correlation and Multiple Regression Analyses for Associations Between Student Outcomes (Attitudes and Achievement) and Five Classroom Environment Scales

Scale	Outcome-Environment Association							
	Attitudes				Achievement Posttest			
	Grade 4		Grade 5		Grade 4		Grade 5	
	r	β	*r*	β	*r*	β	*r*	β
My Class Inventory (MCI)								
Friction	-0.02	0.01	-0.33**	-0.17*	0.00	-0.08	0.01	0.09
Competition	-0.09	-0.05	-0.19*	-0.04	-0.09	-0.08	-0.12	-0.09
Questionnaire on Teacher Interaction (QTI)								
Leadership/ Understanding	0.00	0.01	0.31**	0.14	-0.13	0.06	0.02	-0.07
Uncertain/ Admonishing	-0.15	-0.18	-0.34**	-0.19*	0.06	0.08	-0.19*	-0.19
Science Laboratory Environment Inventory (SLEI)								
Individualization	-0.11	-0.11	0.28**	0.12	0.06	0.01	0.15	0.12
Multiple Correlation *R*		0.05		0.21**		0.06		0.07

* $p < 0.05$, ** $p < 0.01$
Sample size was 120 students in Grade 4 and 145 students in Grade 5.

scales. Students have more positive attitudes to learning mathematics in classrooms perceived to have less Friction, less Competition, more Leadership/Understanding teacher behaviour, less Uncertain/Admonishing teacher behavior, and more Individualization.

For the attitude outcome for the Grade 5 sample, the multiple correlation between attitudes and the set of five classroom environment scales also is statistically significant. The interpretation of the regression coefficients is that Friction and Uncertain/Admonishing teacher behaviour are significant, independent and negative predictors of attitudes.

For the achievement outcome for the Grade 5 sample, the only statistically significant finding that occurred was for the simple correlation between

Uncertain/Admonishing teacher behaviour. Students achieve more in classes of teachers who exhibit less Uncertain/Admonishing behavior (Table 4.13).

4.4.2 Associations Between Student Attitudes and Classroom Environment in Phase 2

In Phase 2 of my study, the third research question involved associations between student attitudes to mathematics (as assessed by the two scales of the TOMRA) and student perceptions of their classroom learning environment (as assessed by the four scales of the WIHIC). All analyses were conducted separately for pretest and posttest data using the sample of 375 students in 20 classes. Also all analyses were conducted for two different units of analysis (the student and the class mean).

The two different types of analysis used were simple correlation analysis and multiple regression analysis using two units of analysis (the student and the class mean). Simple correlations were used to describe the strength of the bivariate associations between each classroom environment scale and each attitude scale. Multiple regression analysis provides a more parsimonious picture of the joint influence of correlated environment variables on attitudes. The standardized regression weight (beta) characterizes the associations between an attitude scale and a particular environment scale when all other environment scales are mutually controlled

The results of the simple correlation and multiple regression analyses for each of the two attitude scales are reported in Table 4.14. The simple correlation (r) data in Table 4.14 indicate that all the associations between a student attitude scale and a learning environment scale are statistically nonsignificant for both pretest and posttest data. Similarly, the results in Table 4.14 also show that the multiple correlation *(R)* was nonsignificant for each attitude scale for both the pretest and the posttest. Overall, the results in Table 4.14 reflect relatively weak associations between the classroom environment and student attitudes for both pretest and posttest data with either the individual or the class mean as the as the unit of analysis.

4.4.3 Summary of Outcome-Environment Associations

In summary, although achievement-environment associations in Phase 1 of the study predominantly were small in magnitude and statistically nonsignificant, still statistically significant bivariate and multivariate associations were found between attitudes to mathematics and classroom environment dimensions for Grade 5 students, but not for Grade 4 students.

For Grade 5 students in Phase 1, the simple correlation results indicated that attitudes to mathematics were more positive in the classrooms with a more positive classroom environment on each of the five scales (i.e. less Friction, less Competition, more Leadership/Understanding behavior, less Uncertain/Admonishing behavior and more Individualization). Moreover, multiple regression analysis revealed that, when the other four learning environment scales were mutually controlled, both Friction and Uncertain/Admonishing behaviour were still significantly associated with students' attitudes to mathematics.

The tentative practical implication from these Phase 1 findings, if replicated in future research, is that Grade 5 students' attitudes toward mathematics could be improved by creating classroom learning environments with less friction among students and with less uncertain/admonishing behavior on the part of the teacher.

In Phase 2 of my study associations between student attitudes and classroom environment were small in magnitude and statistically nonsignificant. These results for my research are unexpected and inconsistent with past research (Fraser, 1998) which has consistently replicated associations between student outcomes and student perceptions of their learning environment. This inconsistency of my findings with past research might have arisen because, although the questionnaires were modified, the language still posed a problem for some students.

TABLE 4.14 Simple Correlation and Multiple Regression Analyses for Associations Between Attitudes and Learning Environment for Two Units of Analysis

Scale	Unit of Analysis	Attitude-Environment Association							
		Adoption of Mathematical Attitudes				Enjoyment of Mathematics Lessons			
		r		*ß*		*r*		*ß*	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post
Student Cohesiveness	Student	0.06	-0.05	0.09	-0.09	-0.01	-0.07	0.04	-0.10
	Class	-0.18	-0.12	0.09	-0.19	-0.17	-0.43	-0.02	-0.53
Teacher Support	Student	0.06	0.03	0.08	0.04	-0.05	0.04	-0.04	0.06
	Class	0.20	-0.09	0.56	-0.12	0.05	-0.09	0.27	-0.05
Task Orientation	Student	0.02	0.04	-0.01	0.06	0.00	0.04	0.05	0.07
	Class	-0.14	0.10	-0.39	0.16	-0.13	0.26	-0.24	0.45
Cooperation	Student	-0.04	0.00	-0.12	0.00	-0.09	-0.03	-0.11	-0.04
	Class	-0.20	-0.03	-0.40	0.08	-0.16	-0.24	-0.21	-0.06
Multiple Correlation, *R*	Student			0.12	0.09			0.10	0.11
	Class			0.48	0.22			0.09	0.60

Sample consisted of 375 students in 20 classes.

4.5 Conclusion

Chapter 4 reported analyses and findings for both phases of my study. Phase 1 involved the pretest and posttest administration of a teacher-made multiple-choice mathematics test, three classroom environment instruments – My Class Inventory (MCI) in actual and preferred versions, Questionnaire on Teacher Interaction (QTI) and Science Laboratory Environment Inventory (SLEI) – and an attitude scale modelled on the Test of Mathematics Related Attitudes (TOMRA). The sample consisted of 422 students in 18 classes in Grades 4 and 5 for Phase 1.

Phase 2 was implemented to improve on the research design in Phase 2. The second phase involved 375 Grades 4 and 5 students in 20 classes in Phase 2. The study was conducted in five elementary schools. In particular, Phase 2 made use of the well established What Is Happening In this Class? to assess classroom environment. Also an improved two-scale version of the Test of Mathematics Related Attitudes was employed.

My study's first research question involved the validity and reliability of the classroom environment questionnaires and mathematics attitude scales. In order to check the factor structure of each classroom environment instrument, a separate principal components factor analysis with varimax rotation was conducted for each questionnaire. Because of the small number of items per scale in Phase 1 – 15 items in 5 scales for the My Class Inventory (MCI), 12 items in four scales for the Questionnaire on Teacher Interaction (QTI), and 15 items in five scales for the Science Laboratory Environment Inventory (SLEI) – it was not possible to replicate the *a priori* factor structure of each instrument. However, analyses of Phase 2 data provided strong support for the factorial validity of the WIHIC and TOMRA.

The internal consistency reliability of MCI, QTI and ICEQ scales in Phase 1 was minimally satisfactory, but was quite strong for two units of analysis for the WIHIC and TOMRA in Phase 2. As well, most environment scales in each phase of the study were found to be capable of differentiating significantly between the perceptions of students in different classrooms.

The second research question involved the effectiveness of using hands-on manipulatives in mathematics instruction in terms of classroom environment, student attitudes and student achievement. A comparison group of students using manipulatives more frequently with a group using manipulatives less frequently in Phase 1 revealed that the only statistically significant findings was that the more frequent use of manipulatives was associated with less classroom friction. In Phase 2, the use of manipulatives was associated with small and statistically nonsignificant changes in classroom environment, attitudes and achievement.

For the third research question concerning association between students' outcomes (attitudes and achievement) and their classroom environment perceptions, Phase 1 produced some statistically significant associations between Grade 5 students' attitudes and all learning environment scales. In Phase 2, however, my results were inconsistent with past research in that outcome-environment relationships were weak and statistically nonsignificant.

CHAPTER 5

SUMMARY

5.1 Introduction

This study involved an evaluation of the effectiveness of hands-on activities, achievement, learning environment, and attitudes of students in Grades 4 and 5 in elementary schools in the Miami-Dade County Public schools (MDCPS) district, Florida, USA. The other two main research questions involved: validation of measures of classroom environment and students' attitudes toward mathematics; and investigation of relationships between classroom environment and student outcomes.

My study was conducted in two phases. In Phase 1, there were some research design weaknesses and also many of the students had difficulty in reading the questionnaire items. Phase 2 of my study overcame some of these problems and used a broader sample in four elementary schools. Participants shared socio-economic conditions where parents have two or three jobs and English is usually the second language spoken at home. The reading levels of the participants are on or below grade level. In Phase 2, the questionnaires were offered online, which is a preferred method for the students.

Because the planned sample size for the first phase was limited for various reasons, Phase 2 was undertaken. For example, the first phase of the study was narrow because it involved just one school, whereas Phase 2 sought to correct this by involving four elementary schools in the diverse Miami-Dade County Public Schools

(MDCPS) district with a further 375 fourth and fifth graders. Another important problem was that the questionnaires in Phase 1 had too few items to enable the researcher to establish strong levels of reliability and validity. Therefore, in Phase 2, I used the What Is Happening In this Class? (WIHIC) to assess classroom environment and two scales based on the Test of Science Related Attitudes (TOSRA) to assess attitudes toward mathematics.

5.2 Summary of the Thesis

The thesis is summarized below using the following subheadings: Section 5.2.1 summarizes Chapter 1; Section 5.2.2 deals with the literature reviewed; Section 5.2.3 summarizes the research methods; Section 5.2.4 summarizes results for the validity and reliability of the learning environment and attitude survey instruments; Section 5.2.5 summarizes results about the effectiveness of hands-on mathematics activities in terms of student outcomes and learning environment; and Section 5.2.6 summarizes findings concerning associations between student outcomes and their classroom environment perceptions.

5.2.1 Summary of Chapter 1

Chapter 1 provides a brief background to the study, including information about the field of learning environments, and some of the problems facing the education system in the state of Florida, and particularly Miami-Dade County, at the elementary school level. This chapter also considers some of the implications of my study in relation to each research question.

The first objective of this study was delineated as being whether it is possible to develop and validate measures of classroom environments and student attitudes towards mathematics. This objective was accomplished mainly through the factor analysis of classroom environment instruments (MCI, QTI, and SLEI) in Phase 1 and WIHIC in Phase 2, with a separate principal components analysis with varimax rotation conducted for each questionnaire.

5.2.2 Summary of Literature Review Chapter

A review of relevant literature that served as a foundation for gaining a better understanding of previous research relevant to my study is presented in Chapter 2. Literature related to the field of learning environment is reviewed and a historical background to the field of learning environments is provided along with a brief description of the conceptualization and measurement of the learning environment used in past studies. In particular, because my study utilized learning environment scales, a comprehensive review of existing learning environment instruments are provided in this chapter. The remainder of the chapter includes an overview of past studies related to the field of learning environments. Research on interpersonal teacher behavior is presented, including the importance of teacher interaction and development of the Questionnaire on Teacher Interaction (which was used in Phase 1 of this study). Also, a review of some literature related to students' attitudes is presented.

5.2.3 Summary of Research Methods Chapter

Chapter 3 of my study describes the research methods, sample sizes, procedures for collecting data, survey instruments, and how the data were analyzed. My study modified existing questionnaires to make them suitable for assessing the learning environments of elementary students in predominantly Hispanic communities whose native language is not English and whose reading levels are mostly below grade level. This investigation included measures of classroom environment and student attitudes, as well as a teacher-made multiple-choice mathematics achievement test. The sample in Phase 1 consisted of 442 Grades 4 and 5 students in 18 classes in one Miami-Dade County Public School (MDCPS), whereas the sample in Phase 2 consisted of 375 students in 20 classes in four schools.

Three instruments for assessing the learning environments were used in Phase 1: the My Class Inventory (MCI) developed primarily for use at the primary school level (Fisher & Fraser, 1981; Fraser, Anderson & Walberg, 1982; Fraser & O'Brien, 1985); the Questionnaire on Teacher Interaction which originated in The Netherlands and focuses on the nature and quality of interpersonal relationships between teachers and students (Creton, Hermans, & Wubbels, 1990; Wubbels, Brekelmans & Hooymayers, 1991; Wubbels & Levy, 1993); and the Science Laboratory Environment Inventory (SLEI) developed by Fraser (1989a). In Phase 2, the What Is Happening In this Class? (Aldridge, Fraser & Huang, 1999) was chosen for assessing classroom environment. In addition, student attitudes toward mathematics were assessed using scales and items modified from the Test of Science-Related Attitudes (TOSRA), but with somewhat different versions in Phases 1 and 2.

5.2.4 Results for Validity and Reliability of Environment and Attitude Scales

Chapter 4 reports the data analysis pertaining to my first research question concerning the validity and reliability of questionnaires assessing students' perceptions of their classroom learning environment and their attitudes to mathematics. In Phase 1, data were obtained from a sample of 442 students in Grades 4 and 5 at a predominantly Hispanic elementary school in the Miami-Dade County Public Schools (MDCPS) district. Factor analysis of the data for Phase 1 (reported in Section 4.2.1) was undertaken for modified and shortened versions of the QTI, MCI, and the SLEI. A separate principal component factor analysis with varimax rotation was conducted for each questionnaire. Because the sample was too small to conduct factor analysis separately for Grades 4 and 5, the combined sample (*N*=442) was used. Because of the small number of items per scale (12 items for the four scales of the QTI, and 15 items in the five scales for the MCI, and 15 items in the 5 scales for the SLEI), it was not possible to replicate the *a priori* factor structure of each instrument. Analysis of the (QTI) showed the two *a priori* scales with a positive connotation came together into one factor, and two *a priori* scales with a negative connotation came together.

Although the internal consistency reliability (Cronbach alpha coefficient) for some MCI, QTI and SLEQ scales are not high, all values can be considered minimally satisfactory for these short scales which contain from 4 to 8 items.

In contrast to Phase 1, Phase 2 produced strong evidence to support the validity and reliability of the instruments used to assess classroom environment and attitudes to mathematics. Both the WIHIC and two-scale version of TOMRA in Phase 2 displayed strong factorial validity and internal consistency reliability with a sample of 375 students.

5.2.5 Results for Evaluation of Hands-on Manipulatives in Terms of Achievement, Attitudes and Classroom Environment

The second research question asks whether the use of hands-on manipulatives is effective in terms of achievement, attitudes, and classroom environment among students in predominantly Hispanic schools within the Miami-Dade County Public Schools (MDCPS) district. In terms of pretest-posttest changes in achievement in Phase 1, the magnitudes of differences were only of modest size, but still they were statistically significant.

The second research question also involved the effectiveness of using hands-on manipulatives in mathematics instruction in terms of classroom environment and students attitudes. A comparison of a group of students using manipulatives more frequently with a group using manipulatives less frequently in Phase 1 revealed that the only statistically significant findings was that the more frequent use of manipulatives was associated with less classroom friction (effect size of a quarter of a standard deviation). In Phase 2, the use of manipulatives was associated with small and statistically nonsignificant changes in both classroom environment and attitudes.

5.2.6 Findings for Associations Between Students' Outcomes and their Classroom Environment Perceptions

The strongest tradition in past classroom environment research has involved investigation of associations between students' cognitive and affective learning outcome and their perceptions of psychosocial characteristics on their classroom learning environments (Fisher & Fraser, 1982; Haertel, Walberg & Haertel, 1981; McRobbie & Fraser, 1993). In my study, two types of analysis were used: simple correlation analysis which describes bivariate association between each outcome scale and each environment scale; and multiple regression analysis which describes the joint influence of a set of environment scales on each outcome (multiple correlations). The standardized regression coefficient (beta) was used to provide information about which environment scale is independently associated with an outcome when the other environment scales are mutually controlled.

Phase 1 produced some statistically significant associations between Grade 5 students' attitudes and all learning environment scales. In particular, students' attitudes to mathematics were more positive in classrooms with less friction between students and with less uncertain/admonishing teachers. In Phase 2, however, my results were inconsistent with past research in that attitude-environment relationships were weak and statistically nonsignificant. This anomalous finding is discussed further in Chapter 6.

5.3 Conclusion

Chapter 5 was devoted to summarizing the methods and findings for the two phases of my study. In particular, findings were summarized according to the study's three research questions involving, first, the validation of learning environment and attitude scales, second, an evaluation of the effectiveness of using hands-on manipulatives in mathematics instruction in terms of achievement, attitudes and learning environment and, third, an investigation of outcome-environment associations.

CHAPTER 6

DISCUSSION

6.1 Introduction

Chapter 5 was restricted to summarizing the previous chapter of this thesis, with special emphasis on the study's findings. In contrast, this chapter provides a detailed discussion of these findings, the study's shortcomings, its practical implications, and suggestions for future research.

The following headings are used to structure this chapter:

6.2 Reasons for Conducting the Study in Two Phases

6.3 Practical Implications of Findings from the Study

6.4 Anomalous Findings for Outcome-Environment Associations

6.5 Significance of the Study

6.6 Limitations of the Study

6.7 Suggestions for Future Research

6.8 Conclusion

6.2 Reasons for Conducting the Study in Two Phases

My study was conducted in two phases. Because of some shortcomings that emerged in Phase 1, a second phase was undertaken. First, in the Phase 1, it proved difficult to establish strong validity and reliability for the classroom learning environment instruments used (the My Class Inventory, MCI, Science Laboratory

Environment Inventory, SLEI, and Questionnaire on Teacher Interaction, QTI). Some weaknesses were experienced because most of the students spoke English as a second language, because wording of the instruments was modified, and because I reduced the number of items per scale to facilitate the reading demands on students. Therefore, the well-established classroom environment questionnaire, What Is Happening In this Class? (WIHIC), was used in Phase 2 with an adequate number of items per scale.

In Phase 1, attitudes were measured with items based on the Enjoyment of Science Lessons scale of the Test Of Science-Related Attitudes (TOSRA) to form the Test Of Mathematics-Related Attitudes (TOMRA). However, some students were unable to read the items on the questionnaires and others were unable to answer all the questions in the allotted time because of the readability of the instruments for students whose native language was not English. Therefore, in Phase 2, some TOMRA items were simplified and only positively-worded and positively-scored items were used in order to optimize the validity of student responses. Also adequate time for answering this questionnaire was provided to students.

Phase 1 of the study suffered because the planned sample size shrank for various reasons: ESE student population, reading levels of students, etc. To compensate for this in Phase 2, a new sample of a more reasonable size that extended beyond a single school was used. A sample of 422 Grades 4 and 5 students in one elementary school in the Miami-Dade County Public Schools (MDCPS) district participated in Phase 1 of my study. For Phase 2, a representative sample of 375 students in Grades

4 and 5 in four elementary schools in the same diverse school district participated in the study.

Although practical constraints within the school in Phase 1 demanded that all students had the opportunity to use manipulatives to some extent in their mathematics classes, I still was able to compare students who used manipulatives to a greater extent with those who used manipulatives to a lesser extent. In fact, I divided most of the classes into two groups of approximately the same size: those which used manipulatives for the majority of lessons (i.e. more than 60%); and those which used manipulatives for the minority of the lessons (i.e. less than 40%). Therefore, I was able to compare students who used manipulatives for more than 60% of lessons with students who used them for less than 40% of lessons in terms of the classroom learning environment and students' mathematical achievement and attitudes to mathematics.

It is acknowledged that the definition of these two comparison groups (i.e. using manipulatives for more than 60% or less than 40% of lessons) is a weakness in the research design. One could not reasonably expect to detect large differences between two groups of students who all use manipulatives but to varying degrees. However, practical constraints within the school environment necessitated this compromise. For this reason, in Phase 2 of my study, I adopted a different research design in which there was only one group of students who used manipulatives and who responded to pretest and posttest administrations of learning environment and attitude scales.

6.3 Practical Implications of Findings from the Study

There are several implications for students, teachers, administrators and the various stakeholders in education in the state of Florida arising from the results of the present study. In the first place, several widely-applicable instruments have been successfully utilized in the Miami-Dade County Public Schools (MDCPS) district. In terms of measures of classroom environment, the My Class Inventory (MCI), Questionnaire on Teacher interaction (QTI), and Science Laboratory Environment Inventory (SLEI) exhibited a reasonable level of validity, whereas results strongly supported the validity of the widely-applicable What Is Happening In this Class? (WIHIC) questionnaire. As well, the Test of Mathematics-Related Attitudes (TOMRA) was found to provide a valid and reliable means by which teachers can conveniently assess the attitudes of the students.

The availability of classroom environment questionnaires at the elementary school level in the Miami-Dade County Public Schools enables teachers to easily obtain feedback about themselves and their classrooms through student perceptions revealed by these convenient paper-and-pencil instruments. These questionnaires can be administered easily, at little cost, and at a convenient time in the classrooms. These questionnaires can provide feedback to guide teachers in improving their classroom teaching practice. The results of my study provide a starting point from which interested teachers in an elementary school setting could strive to create and maintain favorable classroom learning environments and positive interactions with their students.

Although there is extensive use of hands-on manipulatives in the teaching and learning of mathematics in Miami-Dade County Public School, the pretest-posttest changes in Phase 2 of my study did not support the effectiveness of using manipulatives. Nevertheless, in Phase 1 on my study, the group using manipulatives for more time (60%) perceived significantly less Friction in the classroom than the group using manipulatives for less time (40%). The effect size was approximately a quarter of a standard deviation (0.26), suggesting that the effect is moderate. Although significant differences emerged only for one scale, one could not reasonably expect to find large differences between two groups of students who all use manipulatives but to varying degrees.

Although achievement-environment associations in Phase 1 of the study predominantly were small in magnitude and statistically nonsignificant, still statistically significant bivariate and multivariate associations were found between attitudes to mathematics and classroom environment dimensions for Grade 5 students (but not for Grade 4 students).

For Grade 5 students, the simple correlation results indicated that attitudes to mathematics were more positive in classrooms with a more positive classroom environment on each of the five scales (i.e. less Friction, less Competition, more Leadership/Understanding behavior, less Uncertain/Admonishing behavior and more Indivdualization). Moreover, multiple regression analysis revealed that, when the other four learning environment scales were mutually controlled, both Friction and Uncertain/Admonishing behavior were still significantly associated with students' attitudes to mathematics.

The tentative practical implication from these findings, if replicated in further research, is that students' attitudes toward mathematics might be improved by creating classroom learning environments with less friction among students and with less uncertain/admonishing behavior on the part of the teacher.

6.4 Anomalous Findings for Outcome-Environment Associations

Considerable past research at various grade levels in numerous countries (Fraser, 1994, 1998a; Goh, Young & Fraser, 1995; Haertel, Walberg & Haertel, 1981; McRobbie & Fraser, 1993; Wubbels & Levy, 1993) consistently has found sizeable and statistically significant associations between student-perceived classroom learning environment and student outcomes, especially attitudes. Phase 1 of my study yielded some results that were consistent with past research in that statistically significant associations were found between students' attitudes to mathematics and dimensions of the classroom learning environment.

However, the results of the simple correlation and multiple regression analyses reported in Section 4.4.2 for Phase 2 reflect relatively weak associations between the classroom environment and student attitudes for both pretest and posttest data with either the individual or the class mean as the unit of analysis. This inconsistency of my Phase 2 findings with past research might have arisen because, although the questionnaires were modified, the language still posed a problem for some students. Nevertheless, because Section 3.6.1 reports good support for both the factorial validity and internal consistency reliability of both the learning environment questionnaire (WIHIC) and attitude questionnaire (TOSRA), it would be dubious to explain the absence of attitude-environment associations in terms of the problems that students might have experienced in reading or comprehending these questionnaires.

Because I am unable to identify a plausible explanation of this perplexing lack of attitude-environment associations, there is an urgent need for future research that attempts to replicate this finding. In addition, importantly, future research should incorporate a qualitative data-gathering component so that explanations can be immediately sought for a lack of attitude-environment associations should this pattern emerge again.

6.5 Significance of the Study

Studies such as the present one are important because they have the potential to guide improvements in fourth and fifth grade students' classroom environments and outcomes. There is a need for research that might yield dividends in terms of our understanding of how innovative learning environments could lead to needed improvements in students' attitudes and achievement, especially because international studies reveal that the relative achievement of Western school students had fallen behind Asian schools (TIMSS, 1977). One sobering but important finding from this research is that the benefits of using manipulatives among this sample of mathematics students were somewhat limited and fall short of the level of benefits claimed by proponents of the use of manipulatives.

Another area of significance is the result about how the classroom environment and students' interaction with their teachers can affect student attitudes towards mathematics. For example, preliminary results from Phase 1 suggest that students' attitudes to mathematics are likely to be more positive in classrooms with lower friction among students and with teachers who exhibit less uncertain/admonishing behavior.

In terms of the field of learning environments, this study provides another example of the use of learning environment variables as criteria of effectiveness in evaluating an educational innovation (see also Maor & Fraser, 1996; Nix, Fraser & Ledbetter, 2005; Teh & Fraser, 1994).

6.6 Limitations of the Study

Before the results of the present study can be generalized, there are several considerations that need to be taken into account. Limitations to my study are related to the cultural background of the students, their reading level, time constraints, and the modifications made to the questionnaires to suit the particular students in the diverse community chosen for the study. This section not only identifies potential limitations, but it also describes the various steps that I undertook to minimize the deleterious impact of these limitations.

Miami-Dade County is often described as the gateway to Central and South America, and therefore the majority of the students in the county have English as a second language. The schools have a problem dealing with these multicultural students who find it difficult to read and understand English. Therefore, the wording of some questionnaire items had to be changed in my study to make them more suitable. Also, because the researcher was aware of time constraints that would be in place, the total number of questionnaire items was reduced. Difficulty was experienced in finding a suitable time for collecting data. The instructions for administering the instruments were changed and teachers were allowed to read the directions and instruct students to bubble answer choice on a separate answer sheet. Although the teachers read the questionnaires to the Exceptional Education Students (ESE), they allowed them to bubble in the identification number and write in their ID number and class section on the questionnaires. However, most of these students did not do so correctly.

In particular, in Phase 1, I substantially reduced the number of items contained in each learning environment scale, which had been selected from the MCI, SLEI and QTI. I did this to reduce the reading and time demands on students, most of whom spoke English as a second language and were anticipated to experience serious problems with a long questionnaire.

In hindsight, this was not a wise decision. Analyses reported in Section 4.2.1.1 indicated that it was difficult to obtain satisfactory factorial validity for such short scales. A superior approach would have been to use a smaller number of scales, but with a larger number of items in each scale. In fact, recognition of this weakness in Phase 1 led to the decision to follow an improved approach in Phase 2 in which learning environment scales from the WIHIC were used without any reduction in their original length.

The average time for completing the multiple-choice mathematics test was 45 minutes and for the questionnaire was half an hour. However, the ESE students were given enough time until they were finished, but most of them did not answer the questions correctly. This might partly explain why so many answers were unusable, thus reducing the original sample size of 612 to 442 in Grade 4 and Grade 5.

The generalizability of findings from the present study could be limited by the sample involved. The present study focused on the classroom learning environment in two grades in an elementary setting and, therefore, caution should be exercised before its results are applied to other grades or subject areas or in different settings. In addition, time constraints (mentioned previously) could have led to unexpected selection processes, which could have biased the sample. Those students who did not complete the multiple-choice achievement test and the questionnaire items were generally those who experienced difficulty with reading and comprehending the questions, thus limiting the validity of instruments.

The learning environment and attitude questionnaires used in this study had to be modified to make them more suited to the students' reading and comprehension abilities. It was felt by this researcher that the instruments were too long and that the students' attention span would be too short for such long instruments. However, after modifying these instruments, it was not possible to replicate the *a priori* factor structure for each instrument in Phase 1, possibly because the number of items per scale was too small (15 items in five scales for the MCI, 12 items in four scales for the QTI, and 15 items in five scales for the SLEI). The two samples when combined

(*N*=442). Some wording of the instruments had to be changed to something more familiar to the students.

The smallness of pretest-posttest changes in Phase 2 of this study (see Section 4.3.4) was unanticipated. Originally, it was thought that the experience of working with manipulatives would lead to improvements between pretest and posttest in both the classroom learning environment and student attitudes to mathematics. There are some tentative explanations for the absence of appreciable pre-post changes. First, because the period between pretest and posttest (i.e., when students experienced the use of manipulatives) was quite brief (only nine weeks), it is possible that the 'treatment' period was too short to enable the detection of changes in learning environment and attitudes. Perhaps some students remembered their responses from the pretest and simply repeated them on the posttest. Second, because the questionnaire was administered as an online survey and some students were not experienced in using computers, it is possible that some students could have submitted the survey more than once, thus causing response errors.

Another shortcoming of my study was that qualitative methods were used only sparingly when modifying and trying out the questionnaires. For Phase 1, the researcher interviewed individual students from fourth and fifth grade classes about whether they understood the working and what the questions meant to them. Their answers helped in the modification of the questionnaires. In Phase 2 of the study, however, no further interviews were conducted with individual students about modifications and no other qualitative information was collected. The absence of more comprehensive qualitative research methods in my study is a shortcoming that should be rectified in future research.

Finally, it should be noted that, in an examination-orientated state such as Florida, the data collected in the present study could be subjected to biasing influences such as ‘demand characteristics’, whereby the students might respond in accordance with their perceptions of the expectations of the school, the teacher or the researcher, and ‘impression management’, whereby the students might ‘manage’ their responses to present them in a specific pattern (Hersen & Barlow, 1976). The findings from this study, therefore, should be interpreted with prudence. It might be desirable, therefore, for future quantitative research to be complemented by qualitative methods, which could provide checks on the validity of questionnaires responses and help with interpretation of findings (Fraser & Tobin, 1991; Tobin & Fraser, 1998).

6.7 Suggestions for Future Research

Arising from the findings of the present study, its practical implications, its limitations, and its significance for the elementary classroom learning environments, some suggestions are proposed for further research. Research on classroom environment in elementary schools in the state of Florida generally, and Miami-Dade County in particular, is not very widespread. The present study validated four widely-applicable learning environment instruments for use in elementary school settings: the My Class Inventory (MCI), Questionnaire on Teacher Interaction (QTI), Science Laboratory Environment Inventory (SLEI), and What Is Happening In this Class? (WIHIC). Therefore, one suggestion is that these instruments be used to pursue further classroom environment research in other school districts in the state of Florida so that the results can be compared with the diverse student population of Miami-Dade County Public Schools (MDCPS) district.

Further use of these instruments in different elementary schools with a larger sample size selected from within the school district and the state potentially would be beneficial. Because my study was undertaken in only one elementary school, it would be desirable to replicate the study in other elementary schools. In particular, the sample size in my study turned out to be smaller than planned because of the reading levels and cultural background of the students. It would be interesting to see the findings of my study were replicated in other less-diverse school communities and with larger samples. Such data could provide useful insights into classroom learning environments, student-teacher relationships, attitudes and achievement.

The present study investigated the actual classroom environment of elementary students in a predominantly Hispanic community in Miami-Dade County, Florida. Past research has indicated that it is useful to include students' perceptions of both actual and preferred classroom environment, as well as teachers' perceptions of actual and preferred classroom environment, in the same study. Past studies found that there are differences between students' perceptions of actual and preferred classroom learning environments, and that students' perceptions differ from the teachers' perceptions of the same classroom environment. It also has been reported that students and teachers have different perceptions of actual and ideal interpersonal teacher behavior. Therefore, it would be desirable to extend this line of research to middle and high schools in the state of Florida, so that information obtained could be used for guiding improvements in classroom learning environment and interpersonal teacher behavior (Fraser & Fisher, 1986).

Because the school-level environment is distinct from classroom environment, it could be worthwhile to include teachers' perceptions of the school-level environment. Reports of studies involving both school and classroom environments have been promising (Fisher, Fraser & Wubbels, 1993; Fraser, Docker & Fisher, 1988; Fraser & Rentoul, 1982). Studies incorporating environmental variables at both the school and classroom levels can generate a wealth of information for teachers and administrators to guide the improvement of the working environment in the schools. A study into both school and classroom environments could highlight other factors of school or inter-school differences and could explain variance in student achievement, attitude and behavior that previously have been hidden.

Because interpersonal relationships are very important in education, it would be advantageous to extend investigations into interpersonal relations between school principals and their teachers. In one such study in Israel, Kremer-Hayon and Wubbels (1993) suggested that this could produce interesting results. A study into principal-teacher relationships might provide insights into improving the quality of principal-staff relationship, thereby enhancing the work environment of all concerned (Fisher & Cresswell, 1998).

Tobin and Fraser (1998) recommend the combination of quantitative and qualitative methods in learning environment research. A limitation of my study is that qualitative methods were used only sparingly (involving interviewing selected students about their comprehension of the questionnaires). Therefore, a desirable direction for future research would be more comprehensive use of qualitative data collection in conjunction with learning environment questionnaires.

The above suggestions are aimed at extending the scope of research on classroom learning environments in the state of Florida, particularly at the elementary school level. It is hoped that my study will stimulate more interest in the learning environment and provide research findings that will lead to improvements in students' achievement, attitudes and behavior.

6.8 Conclusion

Overall, the findings of the present study have made several contributions to the field of learning environment at the elementary school level. The study provides various learning environment instruments for teachers to utilize in their classrooms to measure their students' perceptions. Factor and item analysis provided a degree of support for the factorial validity and internal consistency reliability (using Cronbach's alpha coefficient) for these classroom environment scales.

Generally, this study provided only limited support for the efficacy of using hands-on manipulatives in elementary mathematics classes in terms of a range of criteria (namely, classroom environment, attitudes to mathematics and achievement in mathematics). Certainly, further research with other samples and other ways of using manipulatives in the teaching and learning of mathematics is needed for a more complete understanding of the level and nature of the benefits of using manipulatives in different ways with different students.

Finally, the perplexing finding of a lack of attitude-environment associations in the second phase of my research calls for replication studies in which qualitative data gathering can be used to probe reasons behind this finding.

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Appendix A

Multiple-Choice Mathematics Achievement Test

Pre/Posttest

Grade 4

Student ID Number: ______________________________ Score: _______________

Class\Section: __________________

Teacher-made Multiple Choice Items Grade 4

Mathematics Pre\Post FCAT Related Test Items

This achievement test was developed by the author of this thesis for the purposes of this study.

Teacher-made Pre/Post FCAT Multiple Choice Items
Grade Four

The following multiple-choice questions have four answers choices.

Choose the best answer (A, B, C, D). A correct answer is worth 1 point.

1. Land covers ¼ of Earth's surface. Oceans cover the remaining ¾. Which of the following represents the amount of the Earth's surface covered by water?

A. .25

B. .50

C. .75

D. 1.00

2. Dentists tell us we should brush our teeth 2 times a day for 3 minutes each time. How many minutes will you brush your teeth if you do this for five days?

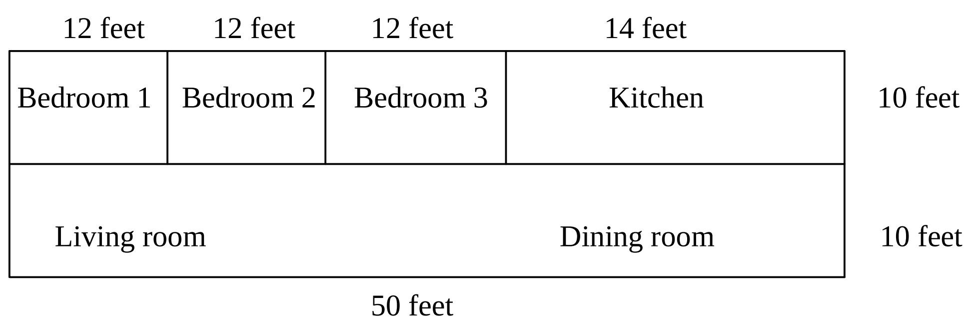
A. 15

B. 25

C. 30

D. 35

3. Mr. Perez, the mason, is putting floor tiles in his house. The tiles will go in the kitchen, the living room and the dining room.



Area = Length x Width

How many square feet of floor tiles will Mr. Perez need?

A. 1, 000 square feet

B. 720 square feet

C. 640 square feet

D. 360 square feet

4. Kevin jogged for four days and recorded the distance he jogged each day.

Days of the week	Number of miles
Sunday	2 miles
Monday	1 1/8
Wednesday	2 1/4
Friday	1 1/2

On which day of the week did Kevin jog the shortest distance?

A. Sunday

B. Monday

C. Friday

D. Wednesday

5. Michele began to put together a 100-piece puzzle. She could not complete the puzzle because there were pieces missing. She counted and found that only 70 of the 100 pieces were in the box. What fraction has a value equal to 70/100?

A. 3/10

B. 6/10

C. 7/10

D. 9/10

6. Amy’s house is 2 km from the library. How many meters is Amy’s house from the library?

A. 200m

B. 20m

C. 2m

D. 2000m

7. A cooler is filled with lemonade. It holds 2 ½ gallons. If each student drinks only 1 cup of lemonade, how many students can have a drink?

1 Gallon = 16 cups

A. 48

B. 32

C. 40

D. 24

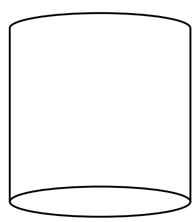
8. Jacqueline drinks a full glass of orange juice every morning. Which is the best estimate for the amount of orange juice her glass can hold?

A. 2 milliliters

B. 20 milliliters

C. 200 milliliters

D. 2000 milliliters



9. Juan has a newspaper route. He has 140 papers to deliver. He can deliver 7 papers in 5 minutes. How long will it take him to deliver all the papers?

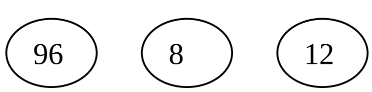
A. 1 hour 30 minutes

B. 1 hour 40 minutes

C. 1 hour 20 minutes

D. 1 hour 25 minutes

10. Each figure has a number. The number could form an equation if the correct symbols were placed between them.



What symbols when used in the order shown, could make a correct equation?

A. divide and equal

B. plus and equal

C. multiply and equal

D. subtract and equal

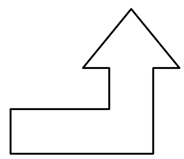
11. How many vertices can be found in the figure below?

A. 9

B. 8

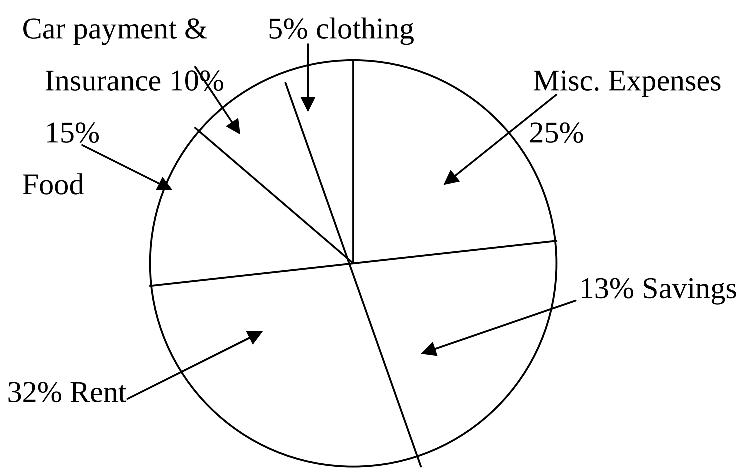
C. 7

D. 6



12. The following circle graph shows the Rodriguez's family monthly budget.

Rodriguez Family Budget



The Rodriguez's spend about $1200 on rent and food combined. Estimate their total monthly budget. Which of the following is the best estimate for their monthly budget?

A. $1600

B. $2500

C. $2000

D. $1800

13. Ms. Hernandez visited 5 schools. The chart below shows the distance in miles that Ms. Hernandez traveled.

Elementary Schools	Miles From Home
Hialeah Gardens Elementary	40 miles
Ben Sheppard Elementary	45miles
Miami Springs Elementary	45 miles
Palm Spring Elementary	20 miles
Norland Elementary School	30 miles

What is the mean number of miles she traveled to the five schools?

A. 27

B. 17

C. 36

D. 54

14. Mrs. Sylvester wants to bake a cake for Mrs. Ali's birthday party. Which of these tools could be used to measure the ingredients for the cake?

A. Compass

B. Thermometer

C. Measuring cup

D. Measuring tape

15. Natalie is organizing her photographs. Each album page holds 6 photos. Let p represent the number of pages in the album. Which expression below could be used to calculate the total number of pictures her album will hold?

A. p /6

B. p x 6

C. p+2

D. p – 6

16. This chart shows the number of butterflies collected by four students during one week. Use the chart to answer the question.

Number of butterflies collected

	M	T	W	T	F
Victor	/	////	///	///// /	//
Melissa	///	///// ///	/	/	///// //
Susan	////	//	/////	//	///
Karen	/	///// /	/	///	/

How many butterflies did Susan collect in all?

A. 10

B. 12

C. 16

D. 14

17. Marvin and Adrian built cars for their After School Building Models Club. Since their 10-inch long cars have no motor, they hope that their cars will coast quickly down the slanted track.
What is a reasonable length for the track?

A. 10 cm

B. 10 meters

C. 1 Kilometre

D. 10 Kilometres

18. Ramon has a collection of 156 marbles. He has an equal number of colours. How many of each colour does he have?

A. 21

B. 56

C. 156

D. 26

19. Suzie is 45 inches tall. Her brother is 29 inches tall. How many inches taller is Suzie than her brother?

A. 12

B. 14

C. 26

D. 16

20. What is the value of 2 in the number 65, 284?

A. 2 tens

B. 2 hundreds

C. 2 thousands

D. 2 ten thousands

21. Ana bought 4 packs of cereals. Each pack cost $1.29.
What is an estimated cost of the 4 packs?

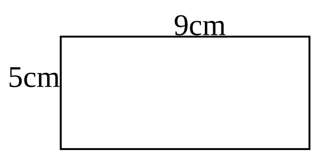
A. $10.00

B. $5.00

C. $2.00

D. $12.00

22. The length of the rectangle is 9 centimeters and the width is 5 centimeters. What is the perimeter of the rectangle in centimeters?



A. 28 centimeters

B. 45 centimeters

C. 18 centimeters

D. 19 centimeters

23. Study the following number pattern. Which two numbers will complete the table?

IN	2	4	6		10	12
OUT	8	16	24	32	40	?

A. 6, 42

B. 8, 42

C. 8, 44

D. 8, 48

24. Eileen received the following scores on her mathematics tests: 80, 70, and 90. What is her mean score?

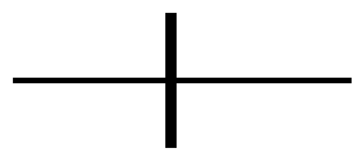
A. 80

B. 85

C. 90

D. 95

25. Mrs. Ali draws this picture of two lines.



Which one of the following four words describes the angles formed in her picture?

A. acute angles

B. right angles

C. obtuse angles

D. straight angles

KEY

1. C
2. C
3. C
4. B
5. C
6. D
7. C
8. B
9. B
10. A
11. A
12. B
13. C
14. C
15. B
16. C
17. B
18. D
19. D
20. B
21. B
22. A
23. D
24. A
25. B

Some of the items contained in this packet were adapted from sample documents produced by the Florida Department of Education and Miami-Dade County Public Schools Testing and Evaluation Department. Other questions were generated from items developed during my tenure as a fourth and fifth grade teacher**.**

Appendix B

Multiple-Choice Mathematics Achievement Test

Pre/Posttest

Grade 5

Student ID Number: ______________________________ Score: _______________

Class\Section: __________________

Teacher-made Multiple Choice Items Grade 5

Mathematics Pre\Post FCAT Related Test Items

This achievement test was developed by the author of this thesis for the purposes of this study.

PRE\POST TEACHER-MADE MULTIPLE CHOICE TEST

GRADE 5

Directions: Solve the problem below and bubble in the letter of the correct answer (A, B, C or D). Each answer is worth 4 points.

1. Joseph and Andrew built cars for their After School Building Models Club. Since their 10-centimeter long cars have no motor, they hope that their cars will coast quickly down the slanted track. What is a reasonable length for the track?

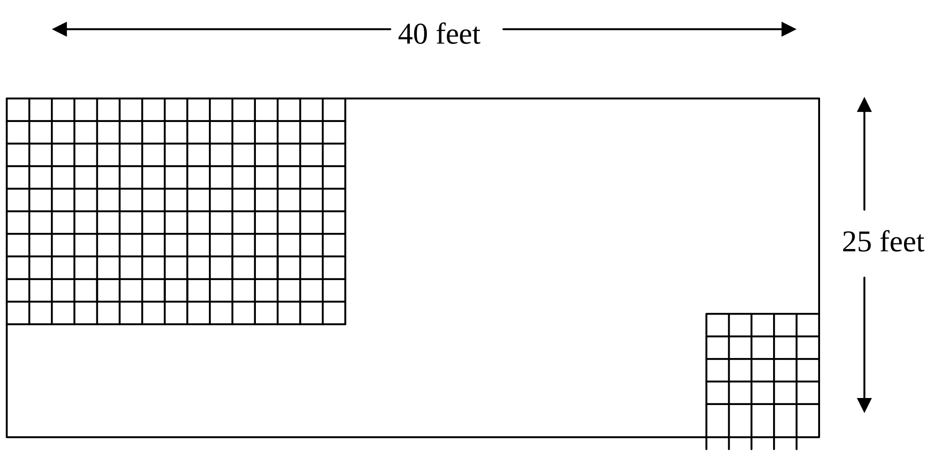
A. 10 meter

B. 1 meters

C. 1 Kilometre

D. 10 Kilometres

2. The Alvarez's family is going to tile their living room floor. The room is 40 feet long by 30 feet wide. The gridded areas have already been tiled, as shown in the diagram. The tiles are one foot by one foot.



How many tiles would they need to complete the floor in this room?

A. 125

B. 825

C. 1000

D. 1025

3. The students in Ms. Davis' class conducted a survey to find their favourite sports team. They surveyed 40 students and recorded the results on the table below. Each tally mark stands for one student. What information is needed to complete the table?

Favourite Sports Team Survey Results

Sports Team	Student Responses	Number of students	Fraction	Decimal	Percent
Panthers	II	2	2/40 or 1/20	0.05	5%
Marlins	IIIII IIIII	10	10/40 or1/4	0.25	25%
Heat	IIIII III	8	8/40 or 1/5	0.20	20%
Dolphins	IIIII IIIII IIIII IIIII	20	20/40 or 1/2		

A. 0.30 and 30%

B. 0.25 and 25%

C. 0.50 and 50%

D. 0.70 and 70%

4. A gallon of milk will fill n cups. Beatriz has 4 gallons.

How many cups will Beatriz fill?

A. 3n

B. 4n

C. 4+n

D. 4-n

5. Jennifer rides her bicycle every day after she finishes her homework.

She made the following chart to show how many miles she rode last week.

Miles Ride per Day

Monday	4
Tuesday	11
Wednesday	8
Thursday	7
Friday	6
Total	n

Which expression shows how far she rode Monday through Thursday?

A. n-6

B. n + 4 + 11+ 7

C. n+6

D. 4 + 8+ 11 + 7

6. Johanna read 45 books in the Reading Competition Championship at her school last year. If Johanna reads one more book, the number of books she read all this year would double the number she read last year. How many books did Johanna read last year?

A. 23

B. 92

C. 34

D. 29

7. Dog racing is a popular sport in Alaska. The most famous annual dog sled race is the 1,200-mile Iditarod from Anchorage to Nome. If one of the drivers completed only 300 miles of the race, find the percentage of the total race to be completed?

A. 30%

B. 50%

C. 75%

D. 25%

8. The table below shows the distance that David, Julio, Adrian, and Andre lives from school.

Student	Distance from School (in Kilometers)
David	0.80 Kilometers
Julio	1.80 Kilometers
Adrian	1.08 Kilometer
Andre	0.08 Kilometer

How many Kilometres from school is the home of the student who lives **nearest** to school?

A. 1.08 kilometre

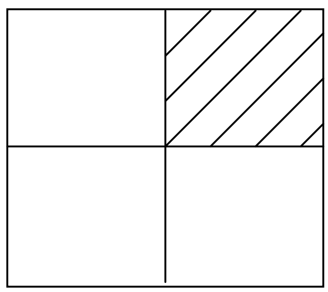
B. 1.80 Kilometre

C. 0.08 Kilometre

D. 0.80 Kilometre

9. Kevin uses ¼ of his room for his drum set.

Expressed as a decimal what is the portion of his room used for drums?



A 0.25

B. 0.50

C. 0. 75

D. 1.00

10. Ms. Lewis surveyed the students in the fifth grade classes to find out what type of Fund-raiser they want to have to help pay for their end of the year party. The table displays the data collected.

Fund-Raiser Choices

	Car wash	Bake sale	Raffle
Girls	12	23	15
Boys	20	8	38

How many more students wanted the Raffle than wanted the Bake sale?

A. 16
B. 22
C. 24
D. 15

11. Ms. Brower averaged her students' mathematics grades for the grading period. She organized the data in a table below.

Math Grades

Number of Students	16	12	4	2
Grade Average	A	B	C	Below C

How many students were in Ms. Brower's mathematics class?

A. 32

B. 34

C. 40

D. 28

12. Look at the number sentence.

7 ☐ 6 ☐ 2 = 40

Which of the following operations will make the number sentence true?

A. plus and minus

B. plus and divide

C. multiply and divide

D. multiply and subtract

13. Fernando earns $20.00 every week for helping his dad. He divides his money as follows:

Savings	$5.00
Snacks	$2.50
Video Games	$5.00
Comics or Toys	$7.50
Total	$20.00

Assuming the same budget, if Fernando earns $28.00, how much in total will he be able to spend on video games?

A. $10.00

B. $12.00

C. $13.00

D. $9.00

14. The dance class stood in rows to have their picture taken.

The photographer told two students to stand in the first row, four students to stand in the second row, and six students to stand in the third row.

If this pattern continues, how many students will be standing in the eighth row?

A. 8

B. 12

C. 16

D. 18

15. One small can of tuna weighs 76 grams. How many grams will a dozen cans of tuna weigh?

A. 812

B. 912

C. 922

D. 932

16. What is the value of **7** in the number 8, 387, 369?

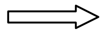
A. million

B. ten

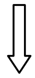
C. thousand

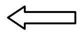
D. hundred

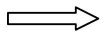
7. Look at the arrow below.

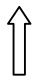


What would the arrow look like if it were flipped over the line?

A. 

B. 

C. 

D. 

18. Study the following number pattern. Which two numbers will complete the table?

IN	2	4		8	10	12
OUT	8	16	24		40	48

A. 6, 8

B. 6, 32

C. 8, 40

D. 8, 48

19. What metric unit would be the most reasonable to use for measuring the width of your classroom?

A. millimeter

B. centimeter

C. meter

D. Kilometer

20. What do all of the following numbers have in common?

2, 3, 7, 11, 13

A. they are all odd numbers

B. they are all prime numbers

C. they are all composite numbers

D. they are all factors of 21

21. Anthony wants to build a fence around his garden to keep chickens out.

His garden is 12 feet by 20 feet. He needs to know how much fencing to buy.

What is the perimeter of his garden?

P = 2*l* + 2*w*

A. 32 feet

B. 68 feet

C. 64 feet

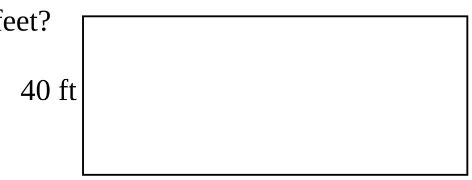
D. 128 feet

22. Ms. Thompson's class is planting a rectangular garden. A diagram of the garden is shown below. The area of the garden is 2,400 square feet.

What would be the lengths, in feet of the longest sides of the garden,

if the shortest side were 40 feet?

A = (l x w) square ft



A. 45 ft

B. 60 ft

C. 80 sq. ft

D. 25 ft

23. The following table shows how fast a humming bird's wings move when the bird hovers in the air. Complete the pattern in the table to show how many wing beats a hummingbird completes in 6 seconds.

Wing Beats of Hummingbirds

Number of seconds	1	2	3	4	5	6
Number of wing beats	70	140	210	280		

A. 480, 560

B. 360, 420

C. 350, 420

D. 140, 280

24. For her birthday party, Patricia wants each of her friends to get 3 cookies and a soda. Her mother has set up 4 tables. There will be 4 friends at each table. How many cookies will she need?

A. 22

B. 36

C. 48

D. 40

25. Ashley has 36 Canadian and British stamps in her collection.

She has 3 times as many Canadian stamps as British stamps.

How many of the stamps are Canadian?

A. 27 stamps

B. 16 stamps

C. 24 stamps

D. 36 stamps

THE END

KEY

1. A
2. B
3. C
4. B
5. D
6. A
7. C
8. C
9. A
10. B
11. B
12. D
13. C
14. C
15. B
16. C
17. B
18. B
19. C
20. B
21. C
22. B
23. C
24. C
25. A

Some of the items contained in this packet were adapted from sample documents produced by the Florida Department of Education and Miami-Dade County Public Schools Testing and Evaluation Department. Other questions were generated from items developed during my tenure as a fourth and fifth grade teacher.

Appendix C

My Class Inventory (MCI) Modified

The My Class Inventory was developed by Fraser and Fisher (1986) and is discussed in Sections 2.6.4 and 3.5.2 of this thesis. It was used in my study and included in this thesis with the permission of the authors.

Student ID# ______________________ **Section:** _________

My Class Inventory (MCI) Modified

Directions:

This is not a test. The questions are to find out what your class is actually like. Each sentence is meant to describe what your actual classroom is like.
Underline: YES you agree with the sentence or **NO** if you **DON'T AGREE** with the sentence.
Example:
27. Most students in our class are good friends.
If you agree that most students in the class actually are good friends, underline the YES like this **YES**
If you don't agree that most students in the class actually are good friends, underline the NO like this **NO**
Please answer all questions. If you change your mind about an answer, just cross it out and underline the new answer.

Remember you are describing your actual classroom	Underline your answer	Teacher's Use only
1. The students enjoy their school work in my class	YES NO	______
2. Students are always fighting with each other.	YES NO	______
3. Students often race to see who can finish first.	YES NO	______
4. In my class the work is hard to do.	YES NO	______
5. In my class everybody is my friend.	YES NO	______
6. Some students are not happy in my class.	YES NO	______
7. Some students in my class are unfriendly.	YES NO	______
8. Most students can do their schoolwork without help.	YES NO	______
9. Most students in my class are not my friend.	YES NO	______
10. Students seem to like my class.	YES NO	______
11. Many students in my class like to fight.	YES NO	______
12. Some students feel bad when they don't do as well as the others.	YES NO	______
13. All students in my class are close friends.	YES NO	______
14. Some students don't like my class.	YES NO	______
15. Some students always try to do their work better than the others.	YES NO	______

For Teacher's Use Only: S ___ F ___ Cm ____ D _____ Ch _____

This page is supplement to a publication entitled Assessing and Improving Classroom Environment adapted from one authored by Barry J. Fraser, and published by National Key Centre, Curtin University of Technology, Australia. 1989.

Appendix D

Modified Laboratory Environment Inventory

The Science Laboratory Environment Inventory (SLEI) was developed by Fraser, Giddings and McRobbie (1995) and is discussed in Sections 2.6.7 and 3.5.2. It was used in my study and is included in this thesis with the permission of the authors.

Student ID#: ______________________ **Section: __________**

MODIFIED LABORATORY ENVIRONMENT INVENTORY

Actual Form

Directions:
This questionnaire contains statements about practices which could take place in this mathematics class. You will be asked **how often** each practice **actually takes place.** There is ‘no right’ or ‘wrong answer’. Your opinion is wanted.

Think about how well each statement describes what this mathematics class is actually like for you. Draw a circle around

1	if the practice actually takes place	**ALMOST NEVER**
2	if the practice actually takes place	**SELDOM**
3	if the practice actually takes place	**SOMETIMES**
4	if the practice actually takes place	**OFTEN**
5	if the practice actually takes place	**VERY OFTEN**

Be sure to answer all questions. Some questions are fairly similar to other statements. Don’t worry about this. Simply give your opinion about all statements.

Remember that you are describing your actual classroom	Almost Never Seldom Sometimes Often Very Often	For Teacher’s use
1. I get on well with students in this mathematics class.	1 2 3 4 5	_______
2. There is opportunity for me to write my own mathematics problems in this class.	1 2 3 4 5	_______
3. What I do in our regular mathematics class is not related to other class work.	1 2 3 4 5	_______
4. My mathematics class has clear rules to guide my activities.	1 2 3 4 5	_______
5. My mathematics class is often hot and stuffy.	1 2 3 4 5	_______
6. I have little chance to know other students in this mathematics class.	1 2 3 4 5	_______
7. I am allowed to go on to other problems when I complete assigned tasks.	1 2 3 4 5	_______
8. I practice with manipulatives before I do assigned activities.	1 2 3 4 5	_______
9. My mathematics class allows me to work at my own pace.	1 2 3 4 5	_______
10. The materials I need for mathematics activities are readily available.	1 2 3 4 5	_______
11. Students in this class are helpful.	1 2 3 4 5	_______
12. I am allowed to go beyond the regular mathematics exercises and do more on my own.	1 2 3 4 5	_______
14. What I do in regular class is usually what I get on the test.	1 2 3 4 5	_______
15. My mathematics class has enough room for cooperative groups.	1 2 3 4 5	_______

For Teacher’s Use Only: SC _____ OE ____ I _____ RC _____ ME _____

Appendix E

Questionnaire on Teacher Interaction (QTI) Modified

The Questionnaire on Teacher Interaction (QTI) was developed by Wubbels (1993) and is discussed in Sections 2.6.6 and 3.5.2. It was used in my study and is included in this thesis with the permission of the author.

Student ID# ____________________ **Section: _____________**

Questionnaire on Teacher Interaction (QTI)

Student Questionnaire (Modified)

Directions:

This questionnaire asks you to describe the behavior of your teacher. This is NOT a test. Your opinion is what is wanted.

This questionnaire has 12 items about the teacher. For each sentence, circle the number corresponding to your response. For example:

	Never				**Always**
The teacher expresses himself/herself clearly.	0	1	2	3	4

	Never Always	Teacher's Use
1. The teacher talks enthusiastically about his/her subject.	0 1 2 3 4	Lea Und
2. The teacher trusts us.	0 1 2 3 4	Unc
3. This teacher seems uncertain.	0 1 2 3 4	Adm
4. The teacher gets angry unexpectedly.	0 1 2 3 4	
5. The teacher explains things clearly.	0 1 2 3 4	Lea
6. If we don't agree with the teacher, we can talk about it.	0 1 2 3 4	Und
7. The teacher acts as if he/she does not know what to do.	0 1 2 3 4	Unc
8. The teacher is patient.	0 1 2 3 4	Adm
9. The teacher acts confidently.	0 1 2 3 4	Lea
10. The teacher is willing to explain things again.	0 1 2 3 4	Und
11. The teacher is not sure what to do when we fool around.	0 1 2 3 4	Unc
12. The teacher is too quick to correct us when we break a rule.	0 1 2 3 4	Adm

For Teacher's Use Only: Lea _______ Und ________ Unc ________ Adm _________

Appendix F

Student Attitude Scale

The Student Attitude Scale was adapted from the Test Of Science-Related Attitudes (TOSRA) that was developed by Fraser (1981) for use in mathematics and which is discussed in Section 3.1. It was used in my study and is included in this thesis with the permission of the author.

Student Attitude Scale

ATTITUDE SCALE		Almost Never	Seldom	Some-times	Often	Almost Always
1.	I look forward to mathematics lessons.	1	2	3	4	5
2.	Mathematics lessons are fun.	1	2	3	4	5
<u>3</u>.	I dislike mathematics lessons.	1	2	3	4	5
<u>4</u>.	Mathematics lessons bore me.	1	2	3	4	5
5.	Mathematics is one of the most interesting school subjects.	1	2	3	4	5
6.	I enjoy mathematics lessons.	1	2	3	4	5
<u>7</u>.	Mathematics lessons are a waste of time.	1	2	3	4	5
8.	Mathematics lessons make me interested in mathematics.	1	2	3	4	5

Items underlined are scored in reverse.
Items are scored a 1, 2, 3, 4, and 5, respectively, for the responses Almost Never, Seldom, Sometimes, Often and Almost Always (except for those underlined which are scored in reverse).

Appendix G

What Is Happening In this Class? (WIHIC)

and

Test Of Mathematics-Related Attitudes (TOMRA)

Items 1–45 in this appendix are based on the What Is Happening In this Class? (WIHIC) developed by Fraser, Fisher and McRobbie (1996). The WIHIC is discussed in Sections 2.6.9 and 3.5.4. Items 46–61 are based on the Test Of Science-Related Attitudes (TOSRA) developed by Fraser (1981). The TOSRA is discussed in Section 3.5.5. These questionnaires were used in my study and are included in this thesis with the permission of the authors.

Your Opinion about This Class?

This questionnaire contains statements about this mathematics class. You will be asked how often each statement is true.

There are no 'right' or 'wrong' answers. Your opinion is what wanted.

Think about how well each statement describes what this class is like for you.

Click the button below the phrase that you believe shows how you feel:

Almost Never	Seldom	Sometimes	Often	Almost Always

Be sure to give an answer to all questions. If you change your mind about an answer, just click on another choice.

Some statements in this questionnaire are fairly similar to other statements. Don't worry about this. Simply give your opinion about all statements.

1. Name

2. ID

3. Gender

- Male
- Female

4. Grade

5. Section

SC

	Almost Never	Seldom	Sometimes	Often	Almost Always
6. I make friends among students in this class.					
7. I know other students in this class.					

8. I am friendly to students of this class.					
9. Students of this class are my friends.					
10. I work well with other class students.					
11. I help other students who are having trouble with their work.					
12. Students in this class like me.					
13. In this class I get help from other students.					

TS

	Almost Never	Seldom	Sometimes	Often	Almost Always
14. The teacher takes a personal interest in me.					
15. The teacher goes out of his/her way to help me.					
16. The teacher considers my feelings.					
17. The teacher helps me when I have trouble with the work.					
18. The teacher talks with me.					
19. The teacher is interested in my problems.					
20. The teacher moves about the class to talk with me.					
21. The teacher's questions help me to understand.					

INV

	Almost Never	Seldom	Sometimes	Often	Almost Always
22. I discuss ideas in this class.					
23. I give my opinions during class discussions.					
24. The teacher asks me questions.					

	Almost Never	Seldom	Sometimes	Often	Almost Always
25. My ideas and suggestions are used during classroom discussions.					
26. I ask the teacher questions.					
27. I explain my ideas to other students.					
28. Students discuss with me how to go about solving problems.					
29. I am asked to explain how I solve problems.					

TO

	Almost Never	Seldom	Sometimes	Often	Almost Always
30. Getting a certain amount of work done is important to me.					
31. I do as much as I set out to do.					
32. I know the goals of this class.					
33. I am ready to start this class on time.					
34. I know what I am trying to accomplish in this class.					
35. I pay attention during this class.					
36. I try to understand the work in this class.					
37. I know how much work I have to do.					

CO

	Almost Never	Seldom	Sometimes	Often	Almost Always
38. I cooperate with other students when doing assignment work.					

39. I share my books and resources with other students when doing assignments.					
40. When I work in groups in this class, there is teamwork.					
41. I work with other students on projects in this class.					
42. I learn from other students in this class.					
43. I work with other students in this class.					
44. I cooperate with other students on class goals.					
45. Students work with me to achieve class goals.					

AD

	Almost Never	Seldom	Sometimes	Often	Almost Always
46. I enjoy reading about things which disagree with my previous ideas.					
47. I like repeating mathematics problems to check that I get the same results.					
48. I am curious about the world in which we live.					
49. I like to listen to people whose opinion is different from mine.					
50. I find it interesting to hear about new ideas.					
51. In doing mathematics, I like to use new methods which I have not used before.					
52. I am willing to change my ideas when evidence shows that the ideas are poor.					

53. I like listening to other people's ideas.	◻	◻	◻	◻	◻

EN

	Almost Never	Seldom	Sometimes	Often	Almost Always
54. Mathematics lessons are fun	◻	◻	◻	◻	◻
55. I like mathematics lessons.	◻	◻	◻	◻	◻
56. Schools should have longer mathematics lesson periods.	◻	◻	◻	◻	◻
57. Mathematics lessons interest me.	◻	◻	◻	◻	◻
58. Mathematics is one of the most interesting school subjects.	◻	◻	◻	◻	◻
59. I enjoy mathematics lessons.	◻	◻	◻	◻	◻
60. The activities done in mathematics class are interesting.	◻	◻	◻	◻	◻
61. I look forward to mathematics class.	◻	◻	◻	◻	◻

Submit Your Responses

Appendix H

Teacher Survey Form

This survey is designed to assess your use of hands-on manipulatives in the five mathematics strands. It is solely for the use of the researcher. The results obtained will not be used in any way to evaluate the participant.

Check the one that most applies to you**.**

☐ In my mathematic class/ classes I use hands-on manipulatives for 60% or more on all five mathematical strand activities.

☐ In my mathematic class/ classes I use hands-on manipulatives for 40% or less on all five mathematical strand activities.